1609/507.

The ART of DIALLING,

Performed

GEOMETRICALLY, by *Scale* and *Compasses*:
ARITHMETICALLY, by the *Canons* of *Sines* and *Tangents*:
INSTRUMENTALLY, by a *Trigonal Instrument*.

The *Geometrical Part* whereof is performed by *Projecting* of the *Sphere* in *Plano*, upon the *Plan* it self, whereby not only the *Making*, but the *Reason* also of *Dials* is discovered.

A second way of *Geometrical Dialling* very Easie, Plain and Universal.

The Third Edition.

To which is added A

SUPPLEMENT;

SHEWING,

How by *Scale* and *Compasses* to inscribe such *Circles* of the *Sphere* into *Sun-Dial-Plans*, that shall shew (besides the hour of the day) the Diurnal Motion of the Sun; his Place in the *Zodiack*; the Time from his Rising, and Setting; *Babilonian*, *Italian*, and *Jewish* Hours; the Point of the Compass upon which the Sun is at any time of the Day, and the Proportions of Shadows to their Heights.

ALSO,

A General and Easie way to project *Hour Lines* upon all kinds of *Superficies* without any regard had to their standing.

AND,

How from a Glass *Horizontally* Placed in the Soyl of a Window, to reflect Hours upon any *Superficies*.

By WILLIAM LEYBOURN, *Philomath.*

LONDON:

Printed for *Thomas Braddyll*, and Sold by the *Booksellers* of *London* and *Westminster*. MDCC.



TO THE

READER.

THIS *Treatiſe of* Dialling (*as in the former* Edition) *conſiſted of* Three Parts: *the Acceptance it hath found, encouraged me to add a* Fourth Part; *namely,* [A Second Way of Geometrical Dialling] *which is performed with great Eaſe and Exactneſs, and may be ſerviceable to the ingenious Practitioner, when the other* Geometrical way (*either by infinite excurſions or remotion of Centres*) *may prove either very* difficult, *or at leaſt* inconvenient; *I have exemplified it only in* Horizontal, Direct North *or* South Recliners, *and in* Vertical *or* Upright Declining Plains, *as of all other the moſt General. The Order of the Four* Parts, *as they are now Printed, are as followeth,* viz.

The firſt Part *is* Geometrical, *and performeth the whole* Doctrine *of* Dialling *by* Scale *and* Compaſſes; *by* Projecting *of the* Sphere *in* Plano *upon the* Dial Plain *it ſelf,* i. e. *By drawing upon the* Plain *ſuch* Circles *of the* Sphere *in their true Poſition, as any way relate to the delineating of the* Hour-lines *upon ſuch a* Plain, *let the* Plain *be in any poſition, and the* Place *in any ſituation, in reſpect of Latitude; by which manner*

of delineation, the Hour-lines, *the place of the* Subſtile, *and* Stile's *height above the* Plain, *ſhall naturally fall in their due places upon the* Plain, *having no other conſideration, than only knowing how the* Circles *of the* Sphere *are poſited upon the* Globe *it ſelf; which will be ſufficient to carry you through the whole* Work. *And to that end (after ſome few neceſſary* Geometrical Problems) *at the beginning of the Book, I have inſerted ſome* Aſtronomical Elements *alſo, giving the Reader a brief account of thoſe* Circles, *and alſo of their ſituation upon the* Globe: *And in the Concluſion of this* firſt Part *I have (as my laſt* Example *of* Declining Reclining Dials; *which Plains of all others, are the moſt difficult to draw Hour-lines upon) ſo* Projected *the* Sphere *for that purpoſe, that not only the* Making, *but the* Reaſon *alſo of the* delineation *of that* Dial *(and conſequently of any other) is demonſtratively diſcovered.*

The ſecond Part *is* Arithmetical, *ſhewing how by* Arithmetical *Calculation (by help of the* Canons *of Artificial* Sines *and* Tangents) *to find the ſituation of any* Plain, *and from thence to* calculate *the true places of the* Stile, Subſtile, *and* Meridian, *as alſo of the* Hour diſtancer, *and that upon all ſorts of* Plains, *from the* Horizontal *or* Vertical, *to ſuch as* Decline *or* Recline, *or* both. *And in this* Part *I have taken my* Examples *(for the moſt part) the ſame as in that fore-going, and that for theſe two* Reaſons *principally.* (I.) *For the ſaving my ſelf the* labour *of* calculating *of ſo many New ones. But* (II.) *and chiefly, for the* Practitioner's *ſatisfaction,*

tisfaction, that he may ſee what harmony *there is between* Arithmetical Calculation *and* Geometrical Projection.

The third Part *is* Inſtrumental, *and teacheth how to delineate Hour-lines upon all ſorts of* Plains, *by help of a* Plain, Cheap, *and* Portable Inſtrument, *which I call a* HOROLOGICAL TRIGON, *by which the* Stile, Subſtile, *and* Hour-lines, *upon any* Plain, *may eaſily and ſpeedily be* Protracted, *having very few lines to draw, but the* Requiſites *themſelves, and in any caſe, ſeldom exceeding the Confines or Limits of the Plain it ſelf. And with this* Inſtrument *and its* Uſe *I conclude this* Treatiſe.

It may now be expected that I ſhould ſhew how to beautifie *or* adorn *theſe* Dials, *by inſcribing upon them other* Spherical *Circles and Lines (beſides the common hours) as the* Equinoctial *and* Tropicks, *the* Parallels *of* Declination, Parallels *of the* Suns Place, *of the* Length *of the* Day, *of the* Suns Riſing *and* Setting, *the* Jewiſh, Italian, *and* Babyloniſh hours, Almicanthera's Azimuths, Circles *of* Poſition, *the* Signs Aſcending, Deſcending, *and* Culminating, *and the like* Spherical Concluſions: *But in regard that (in part) ſome years ſince, I have (in an* Appendix *to a* Book *of* Dialling) *publiſhed a* Geometrical *way of performing many of theſe* Concluſions *upon ſome* Plains, *I was the more willing to omit them in this place at that time; my other occaſions not giving me ſo much leiſure, as to proſecute them things anſwerable to my own* deſire, *or the ingenious Practitioners* ſatisfaction. *But at that time,*

I did

To the READER.

I did promiſe (God willing) that in due time I would publiſh ſomething elſe of Dialling, *and that not only of the making of* Dials *upon* Plains, *but upon* irregular Superficies *alſo, as upon* Cylinders, Cones, *and* Spheres, *both* Concave *and* Convex, *and alſo upon irregular* Concave *or* Convex Superficies, *and that both by* Reflexion *and* Refraxion, *with divers other things of the like nature: All which particulars, I have ſince that time performed, and the* Book *is now in the* Preſs, *an account of the* Title *whereof, and of the particulars therein contained, is given in a* Poſtſcript *at the end of this* Book.

And now, Reader, let me acquaint thee, That in the former Edition *(in regard of my remotion from the* Preſs, *and the* careleſneſs *of the* Printer, *and* groſs ignorance *of his* Corrector, *ſuch ridiculous* faults *and* abſurdities *paſſed the Preſs, that when I came to peruſe the Book, I could hardly (my ſelf) in many places (without due conſideration) underſtand it. But I have purged it from thoſe* Errors *and* Abſurdities *with which it was then burthened, to my vexation, and the great Trouble of the Learner; and now, is far more perfect, and nothing in it deſerving an* Errata. *I this ſecond time recommend it to thee, wiſhing all good ſucceſs in thy Endeavours. And ſo for this time,* Farewel.

Northcot, *Septemb.* 26. 1680.



Will. Leybourn.

A CONNEXTURE OF *GEOMETRICAL PROBLEMES*, AND ASTRONOMICAL ELEMENTS.

PROBL. I.

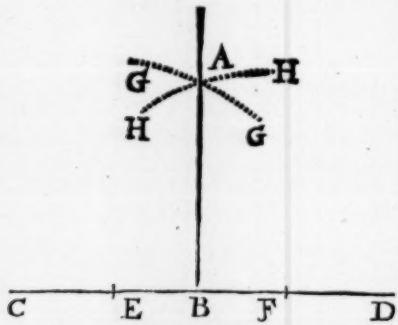
Upon a Right Line given, to erect a Perpendicular.

DEFINITION.

A Right Line is ſaid to be Perpendicular to another Line, when it maketh the Angles on either ſide of the erected Line, equal, that is, ſo that the Line inclines not, either to the right or to the left, but ſtandeth upright upon the Line, upon which it is erected, as in the following Figure, the Right Line A B is ſaid to be perpendicular to the Line C D, upon which it is erected, becauſe the Angles on either ſide thereof are equal; namely the Angle A B C on the one ſide, is equal to the Angle A B D, on the other ſide; and either of theſe Angles are called Right Angles, and the Line A B ſo erected, is called the *Perpendicular*.

PRACTICE.

Let CD be a Right Line given, and let it be required to erect a *Perpendicular* thereupon from the point B: Open your Compaſſes to any convenient ſmall diſtance, and ſetting one Foot in the point B, with the other, make the two marks E and F, on either ſide of the point B. ---This done, open the Compaſſes to any other convenient diſtance greater than the former, and ſetting one in the point E, with the other draw the obſcure Arch G G, as near as you may gueſs over the given point B. Again (the Compaſſes being ſtill opened to the ſame diſtance) ſet one foot in the point F, and with the other Foot deſcribe another obſcure Arch H H, croſſing the former in the point A, ſo is A the point through which, if you draw a right Line from the given point B, that Right Line A B, ſo drawn, ſhall be *Perpendicular* to the given Line C D, and from the point B, as was required.



PROBL. II.

How upon (or near) the end of a given Right Line, *to erect a* Perpendicular.

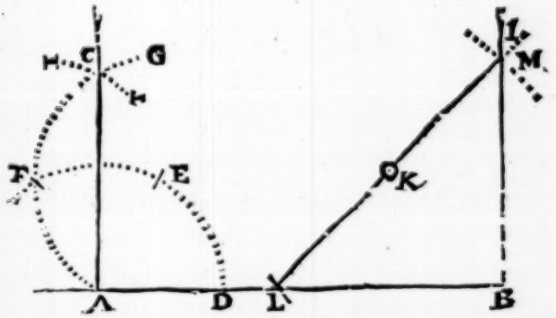
TO effect this, there are ſeveral ways, but I will inſtance only in two, which are familiar and eaſie.



The

The Firſt Way.

Let A B be a Line given, and from the point A, which is towards the end thereof, let it be required to erect a Per-



pendicular A C. ——Firſt, Open your Compaſſes to any ſmall diſtance, and ſetting one foot in the given point A, with the other deſcribe the Arch F E D, then ſet one foot of the Compaſſes in D, (they being opened to the ſame diſtance) croſs the Arch in E, and ſetting one foot in E, with the other deſcribe the Arch A F G croſſing the firſt arch in F. Again, ſet one foot in F, and with the other deſcribe the ſmall arch H H, croſſing the former in the point C: ſo the line A C being drawn, it ſhall be perpendicular to the given Line A B, and from the point A, as was required.

The Second Way.

Let B be the point given, and from it let it be required to draw the line B I, Perpendicular to A B. -----Open the Compaſſes to any ſmall diſtance, and ſetting one foot in the given point B, pitch down the other foot at all adventures, as at K, ſo the one foot being in K, turn the other foot about

till it croſs the given line A B in L, then draw the line K L, and ſet the ſame diſtance K L, (at which the Compaſſes already ſtand) from K to M, ſo a Line drawn from B, through M, ſhall be *Perpendicular* to A B, and from the given point B, as was required.

PROBL. III.

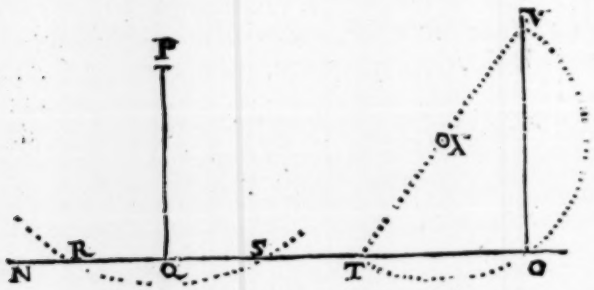
How from a Point above, to let fall a Perpendicular *to a* Right Line *given.*

IN this there are two Caſes. Firſt, when the point above is over (or near) the Middle of the Line. And Secondly, when the Point above is near over the End of the Line.

The Firſt Caſe.

Let N O be a Right Line given, and from the point P, over it, let it be required to let fall the *Perpendicular* P Q.

---Firſt open your Compaſſes to any diſtance greater than



P Q, and ſetting one foot in the given point P, with the other deſcribe an Arch of a Circle, cutting the given line N O, in the points R and S. Then, Secondly, divide the ſpace between

tween R and S in two equal parts in Q, (by the Fourth Probleme following) ſo a line drawn from the given point P, to Q, ſhall be *Perpendicular* to the given line N O.

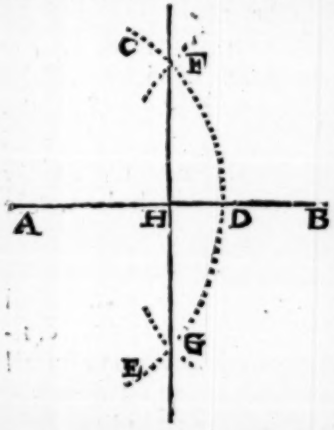
The Second Caſe.

Let V be the point given, from whence to let fall a Perpendicular to the line N O, ----Firſt, from any part of the given line N O, as from T, draw a right Line to the given point V, which Line (by the next Problem) divide into two equal parts in the point X, with that diſtance of the Compaſſes (one foot being placed in X) with the other deſcribe the Arch (or Semicircle) V O T, cutting the given line N O in O, ſo a Line drawn from V to O, ſhall be *Perpendicular* to the given line N O, and towards the end thereof, as was required.

PROBL. IV.

How to divide a Right Line *given, into* Two Equal parts, *and at* Right Angles.

LEt the line A B be a line given, to be divided into two equal parts at Right Angles. Take in your Compaſſes the length of the line A B, or (if that be too long) any other diſtance above half the length thereof, and ſetting one foot in the end A, with the other draw the Arch C D E, (then the Compaſſes unaltered) ſet one foot in B, and with the other foot croſs the former arch (both above and below the line) in the points F and G; then a line drawn from F to G, ſhall cut the given Line in H, ſo ſhall A B be divided in two Equal Parts in the Point H, and at *Right Angles*, which was required.



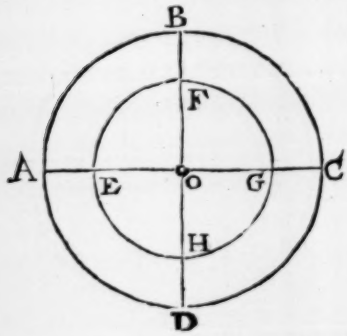
PROBL

PROBL. V.

A Right Line *being given, how to draw another* Right Line, *which ſhall be Parallel thereunto, at any diſtance required, or through any point aſſigned.*

DEFINITION.

OF *Parallel Lines*, there are principally Two kinds, *viz. Streight* or *Right Lined Parallels*, and *Circular Parallels*. All Circles that are deſcribed or drawn upon the ſame Centre, whether they be greater or leſſer one than the other, are ſaid to be *Parallel* or *Concentrick Circles*, as the Circle A B C D, may be ſaid to be a *Concentrick Circle* with, or a *Parallel Circle* to E F G H, becauſe both of them are deſcribed or drawn upon the ſame point or *Centre* O; and of both theſe *Circles*, the right line A C is the *Diameter* of the *Greater Circle*, and E G of the *Leſſer*, the point O is the *Centre* of both, and all Right Lines drawn from thence to the *Perifery*, *Circumference*, or *Limb* of either of the *Circles*, are Equal, and are called ſometimes the *Semidiamiters*, and ſometimes the *Radius* of the Circle, as the lines O C or O B of the *Greater*, and O H and O E of the *Leſſer*: It containing 60 ſuch Degrees or Parts, of which the whole Circle contains 360.



But *Right Lined Parallels*, are ſuch Right Lines, that being drawn upon the ſame Plain, and infinitely extended on either ſide, would never concur or meet, but always in all parts, retain an equal diſtance, and ſuch are the right lines B C, and B D, in the Margin.

B——————C

B——————D

In

In the deſcribing or drawing of Parallel Lines, there may fall out Two *Caſes* or *Varieties*: As,

1. It may be required to draw a *Right Line Parallel* to another *Right Line*, at a *Diſtance* given: Or,
2. It may be required to draw the *Parallel Line* through a *Point* aſſigned.

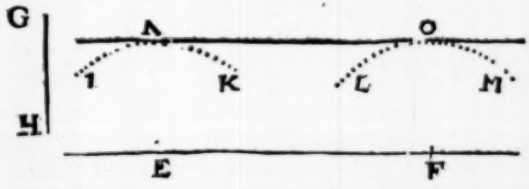
And of this kind there may be two *Caſes*; For,

1. The given *Point* may be *Over* or *Under* the *Given Line*; Or,
2. It may be *Oblique* to the given Line.

PRACTICE.

Of the Firſt Caſe.

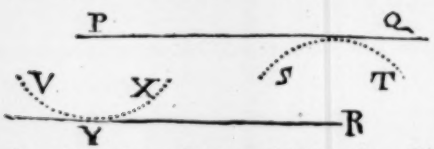
Let E F be a *Right Line* given, and let it be required to draw another Right Line *parallel* thereunto, at the Diſtance of the Points G and H.



Take in your Compaſſes the given diſtance G H, then ſetting one foot of the Compaſſes in E, (or any other point near the ends of the given Line) deſcribe a ſmall obſcure Arch of a Circle, as I K. Then moving the Compaſſes to F (towards the other end of the given Line) deſcribe another obſcure Arch as L M; then lay a Ruler to the very top of theſe two Arches, ſo that the Ruler do not croſs, but juſtly touch either of them: then by the ſide of the Ruler draw the Line N O, and it ſhall be *Parallel* to the given Line E F, and at the diſtance G H, which was required.

The Second Caſe.

Let P Q be a *Right Line* given, and let it be required to draw another Right Line Parallel thereunto, which ſhall paſs through the point R.

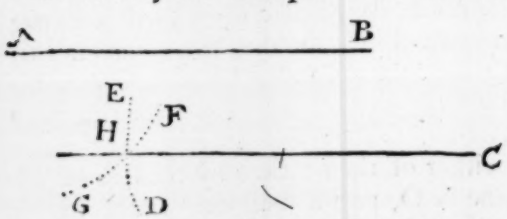


Firſt, Set one foot of your Compaſſes in the given point R, and with the other take the neareſt diſtance to the given Line P Q, which is done by opening or ſhutting of the Compaſſes, till the moveable point do only touch the given line P Q, deſcribing the Arch S T. The Compaſſes ſtill reſting at this diſtance, ſet one foot in P, (or any other points towards the end of the given Line) and with the other foot deſcribe the Arch V X. Laſtly, By the very top of this Arch Y, draw the Right Line Y R, and it ſhall be *Parallel* to the given Line P Q, and ſhall paſs directly through the given Point R, which was required.

The Third Caſe.

Let A B be a *Right Line* given, and let it be required to draw another *Right Line Parallel* thereunto, which ſhall paſs through the *Point* C.

Take in your Compaſſes the diſtance from the given *Point* C, to the end of the given line B, then ſet one foot in A, the other end of the given line, and with the other Foot deſcribe the Arch F G. Again, Take in your Compaſſes the length of the given line A B, and ſetting one foot of that diſtance in C, with the other deſcribe the arch D E, croſſing the former arch in the point H, ſo the Line H C being drawn, ſhall be *Parallel* to the Line A B, and ſhall paſs through the given point C, as was required.

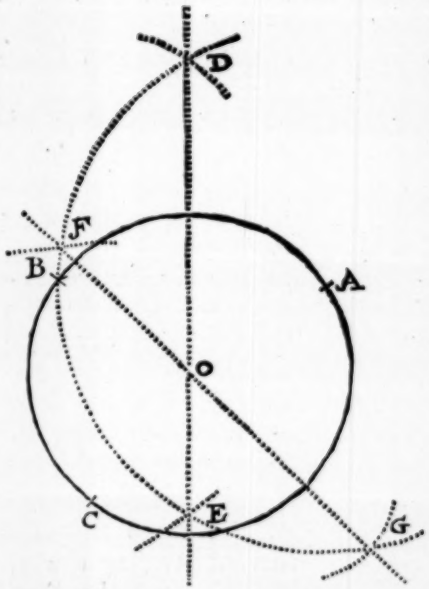


PROBL.

PROBL. VI.

Any Three Points (*which are not in a ſtraight Line*) *being given*; *how to find the* Centre *of a* Circle, *which ſhall paſs through thoſe* Three *given* Points.

LEt the three given points be A B and C, through which it is required a Circle ſhould be deſcribed: Firſt, Set one Foot of the Compaſſes in one of the given points as in A, and extend the other foot to B, another of the Points, and draw the arch of a Circle G F D, -----Secondly, the Compaſſes not altered, ſet one foot in B, and with the other, croſs the former Arch with two ſmall Arches, in the points D and E, and draw the Right Line D E. ---- Thirdly, ſet one foot of the Compaſſes in the third point C, (they ſtill keeping the ſame diſtance) and with the other foot croſs the firſt drawn Arch, G F D, in the points F and G, and draw the Right Line F G, croſſing the former right line D E, in the point O. So is O the *Centre* ſought for; upon which, if you deſcribe a *Circle* at the diſtance O A, it ſhall paſs through all the three given *Points* A B and C, as was required.

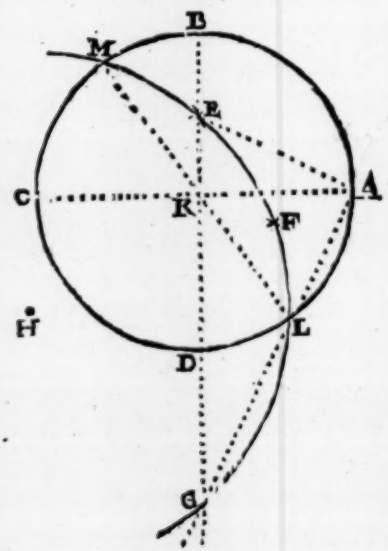


PROBL. VII.

Two Points within a Circle *being given, how to find the* Centre *of a* Circle, *which being deſcribed, ſhall paſs through the Two* Given Points; *and ſhall alſo divide the* Perifery *or* Circumference *of the given* Circle *into* Two equal Parts.

THis and the foregoing Propoſition, come in continual uſe and practice throughout this work, and therefore ought more eſpecially to be minded.

Let the *Circle* given be A B C D, and the two *Points* within the ſame, be E and F.



Firſt, Through either of the given Points (as E,) draw a right line E D, which muſt paſs through the Centre of the given Circle at R. ---- Secondly, To this line B D, draw the line A C, through the Centre, and at right angles to B D --- Thirdly, From the given point E, draw a right line E A, and upon the end thereof A, (by the 2. Probl.) erect the Perpendicular A G, croſſing the Line B D, (it being extended) in the point G, ſo ſhall G be a third point, and then having the three points E F and G, (by the laſt Problem) you

you may find a Centre, upon which a Circle being deſcribed, ſhall paſs, whoſe Centre will be at H, without the given Circle, upon which point, if you deſcribe the arch of a Circle at the extent or diſtance of H E, H F, or H G, it ſhall paſs through the two given *Points* E and F, and ſhall alſo divide the given Circle *A B C D*, into two equal parts in the points M and L, which was required. And that this *Arch* thus drawn doth divide the given Circle into two equal parts is evident, for a Line drawn from L to M, will paſs directly through the Centre of the given Circle, and ſhall therefore divide it into two equal parts.

PROBL. VIII.

How to make a Line *of* Chords *Geometrically, to any aſſigned* Length *or* Radius.

FOraſmuch as through this whole Treatiſe, there is continual mention and uſe made of a Line of *Chords*, it will not be impertinent in this place to diſcover the making thereof, for the convenience of ſuch, as at all times, and in all places, cannot have the benefit of the Mathematical Inſtrument-maker, to whom theſe things are common.

DEFINITION.

A Line of Chords is no other than 60 Degrees of the Arch of any Circle, transferred from the Limb of a Circle to a Streight Line; now every Circle great or ſmall, is divided (or ſuppoſed ſo to be) into 360 equal parts, called *Degrees*, ſo the Semicircle contains 80, the Quadrant 90, and the *Radius* or *Semidiameter* (which is that Line upon which the Circle or Semicircle is deſcribed) noted in the following Figure with the Letters A B, is always equal to 60 degrees of that Circle which it deſcribes, and therefore

60 degrees of a *Line of Chords* is called the *Radius* thereof. Thus much for the *Definition* of a *Line of Chords*, now for

The CONCLUSION.

First, Draw a Right Line of any length, as C B D, and upon the middle thereof, (*by the Firſt or Fourth Problem*) erect the Perpendicular A B.

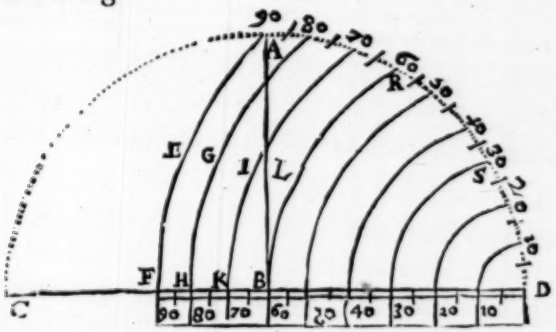
Secondly, Open your Compaſſes to the *Radius*, or length that you would have your Line of Chords to be of, which ſuppoſe A B, (*which I make here equal to the Line of Chords that moſt of the Schemes and Diagrams in this Book were deſcribed by*) and with that diſtance upon B, as a Centre, deſcribe the Semicircle C A D, which is divided into two equal parts or Quadrants by the Perpendicular Line A B.

Thirdly, Divide the Arch or Quadrant A R D, into 90 equal parts or degrees, which you may do in this manner [Take the length of the Line A B, and ſet that diſtance upon the Quadrant A D, from D to R, ſo is D R 60 deg. and A R 30 deg. Then take the diſtance A R, and ſet it from D to S, ſo is the Quadrant divided into three equal parts, at the points S and R, each containing 30 deg. This done, divide the ſeveral ſpaces between A R, R S, and S D, into 3 equal parts, each of which will be 10 deg. according as you ſee the numbers ſet to them, theſe muſt be again divided into two equal parts, each part containing 5 degrees, and every of thoſe into five ſmaller, as you ſee in the Figure, and ſo will the whole Quadrant be divided into 90.]

Fourthly, The Quadrant A R S D being thus divided into 90 parts or degrees, ſet one foot of your Compaſſes in D, and open the other foot to A, and deſcribe the Arch A E F, touching the Line C D in F, ſo is the point F, upon the Right Line C D, the *Chord* of 90 deg.

Fifthly,

Fifthly, Open the Compaſſes from D to 80 deg. and deſcribe the Arch 80 G H, ſo ſhall the point H be the *Chord* of 80 deg.



Sixthly, Open the Compaſſes from D to 70, and deſcribe the Arch 70 I K, ſo is K the *Chord* of 70 deg.

Again, Open the Compaſſes from D to R, the Radius, or 60 deg. and deſcribe the Arch R L B, ſo is B the *Chord* of 60 deg. equal to the Radius.

Do the like with 50, 40, 30, 20 and 10 deg. So ſhall you have the line D F divided into 90 unequal parts called *Chords*.

In this manner may you make a Line of Chords of any length, and ſet it upon a Ruler, and it is fit for to perform all the uſes in this Book, and it were convenient that upon one and the ſame Ruler, you had three, four, or five *Chords* of ſeveral lengths or Radiuſes, as in Practice you will find to be neceſſary and commodious.

Being thus provided of a Line of Chords, I will now ſhew you how to work two Concluſions Geometrically, which are of abſolute uſe in Dialling, *the one is to find the* Hour of the Day, *and the other is to find the* Azimuth *of the* Sun at any time, *and in any place. And with them I ſhall conclude theſe* Geometrical Problemes, *and* Aſtronomical Elements.

Aſtro-

Aſtronomical Elements.

FOr the better underſtanding of that which followeth, the Reader ought to be acquainted with the Principal *Circles of the Sphere*. As alſo, with ſuch other *Lines*, and *Points*, as are deſcribed and noted upon the Material *Sphere* or *Globe*, in imitation of thoſe which are imagined to be in the Heavens. And of ſo many of theſe as are neceſſary for this our preſent purpoſe, I ſhall give you a brief account. Know therefore, that,

DEFINITION.

A *Sphere* or *Globe* is a Solid Body, containing only one Superficies, in whoſe middle there is a Point, from whence all right lines drawn to this Superficies are equal.

The Principal Circles of which a Sphere or Globe is compoſed, are in number *Ten*, whereof *Six* are *great*, and *Four* are *ſmaller* Circles.

A *Great Circle* is that which divideth the Body of the Globe into two equal Parts or Hemiſpheres. A *Small Circle* is that which divideth the Globe into two unequal parts.

The Six Great Circles are,

1 The *Horizon*,
2 The *Meridian*,
3 The *Æquinoctial*,
4 The *Zodiack*,
5, 6 The *Two Colmes*.

The Leſſer Circles are,

1 The *Tropick* of *Cancer*,
2 The *Tropick* of *Capricorn*,
3 The *Artick* Circle.
4 The *Antartick* Circle.

Of theſe in the Art of Dialling there is principally but Five to be taken notice of, *viz.* Three Great Circles, and two ſmaller Circles.

The

The Great Circles are,

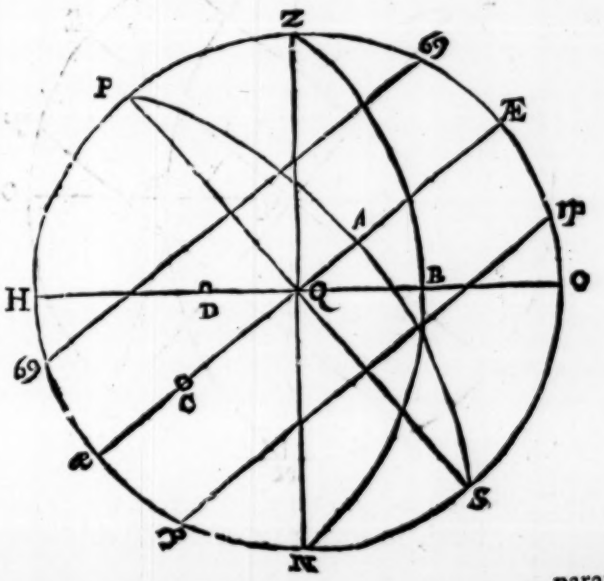
1 The *Horizon,*
2 The *Meridian,*
3 The *Æquinoctial.*

The Leſſer Circles are,

1 The *Tropick* of *Cancer,*
2 The *Tropick* of *Capricorn.*

I. *Of the* HORIZON.

In the following Figure, let the outermoſt Circle thereof, noted with the Letters HZON, repreſent a Sphere or Globe, then the Horizon is a Circle which divideth or ſe-

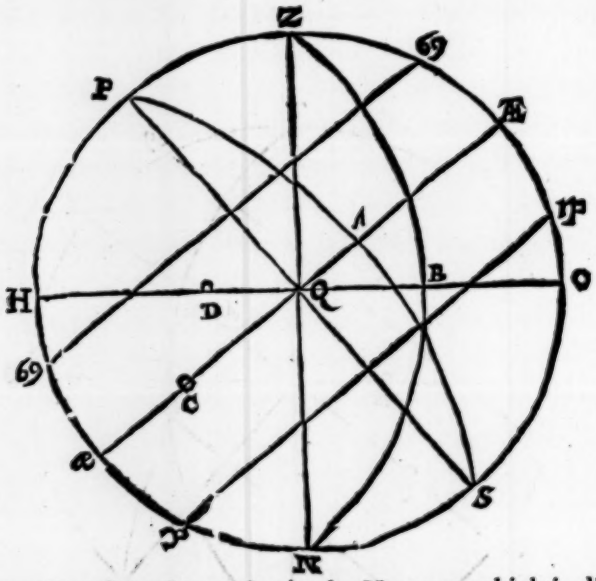


parateth

parateth the visible part of the Heavens which we see, from the invisible part which we see not, and is represented in the following Figure by the Line (which represents a great Circle) H Q O, separating the visible Hemisphere H Z O, which we see; from the invisible part thereof H N O, which we see not.

II. *Of the* Meridian.

The *Meridian* is a Great Circle of the Sphere which passeth by the *Poles* of the World, and through the *Zenith* and *Nadir* of the Place. To this Circle, when the Sun cometh, he being above our Horizon, maketh Noon or Mid-day, and being in the same Circle, when it is under the Horizon, it is then Midnight.



The *Zenith* is that point in the Heavens which is directly over your head, in what part of the World soever you be. And,

The

The *Nadir* is that point in the Heavens which is under your feet, directly oppoſite to the Zenith.

The Meridian Circle in this Figure, is noted with the Letters H Z O N, the point Z at the top repreſenting the *Zenith*, and *N* the *Nadir* Points.

III. *Of the Æquinoctial.*

The *Æquinoctial* is a great Circle of the Sphere, dividing it into the Northern and Southern Hemiſpheres, which take their names from the two Poles, that being called the *Northern Hemiſphere*, in which the *North Pole* is ſeated, and that the *Southern* in which the *South Pole* is ſeated. Unto this Circle when the Sun in his Annual motion arriveth (which is but twice in the whole Year) the Days and Nights are of equal length through the whole World.

This Circle cutteth the Axis of the World at Right Angles, and is ſeated in the Heavens 90 deg. or a Quarter of a Circle, diſtant from either of the Poles.

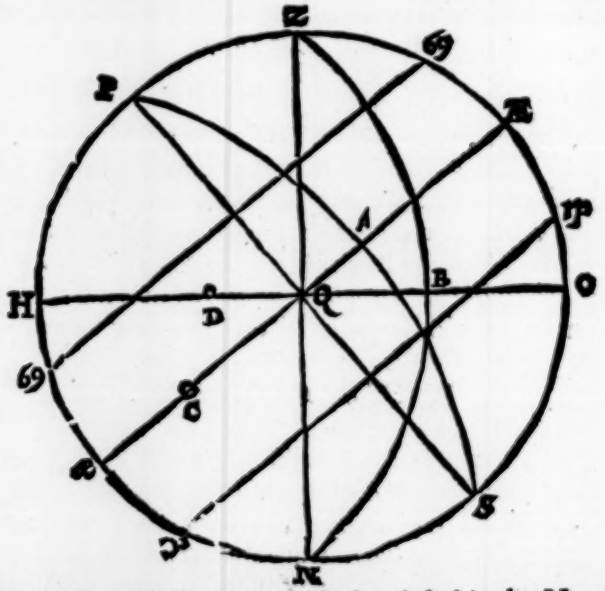
It is repreſented in this Figure by the Line or Circle Æ Q æ. The two Poles are noted with P and S; P being the *North*, and S the *South Pole*; and ſo the Hemiſphere, æ P Æ, is the *Northern*, and Æ S æ the *Southern Hemiſphere*. And the Right line P Q S, is the *Axis of the World*, croſſing the *Æquinoctial* at Right Angles in Q, the Centre, or middle point of the *Sphere* or *Globe*.

IV. *Of the two Tropicks.*

The two Tropicks are *Smaller Circles* of the *Sphere* deſcribed parallel to the Æquinoctial Circle, and at 23 deg. and a half diſtant therefrom; that being the greateſt *Declination* that the Sun hath from the *Æquinoctial* towards either of the *Poles*. Of theſe Circles one is called the *Tropick of Cancer*, or Northern Tropick; the other the *Tro-*

pick of Capricorn, or Southern Tropick, ſo denominated, from the Poles which they reſpect or behold. As the Tropick of Cancer, marked with the character of *Cancer* ☋ ☋ at each end thereof, beholdeth P, the *North Pole*, and the Tropick of Capricorn, noted with the characters of *Capricorn*, ♑ ♑, at each end thereof reſpecteth *S*, the South Pole.

Theſe two Circles are the bounds or limits of the Suns courſe, for between them he always moveth, never going more Northward or Southward, (that is, declines not nearer to any of the Poles) than 23 deg. 31 min. Wherefore, when the Sun in his annual courſe, ſhall arrive to the Tropick of *Cancer*, which is about the 10*th*. or 11*th*. of *June*, he maketh the *Longeſt Days* to all that inhabit in the Northern Hemiſphere. And when he arriveth to the Tropick of *Capricorn*, which is about the 11*th*. of *December*, he ma-



keth the *Shorteſt Days* to thoſe that inhabit the Northern, and the Longeſt to thoſe of the Southern Hemiſphere.

Beſides

Beſides theſe Circles here named, there are divers others deſcribed upon the Globe, Two ſorts whereof, are of great uſe in Dialling, and therefore I ſhall make them known, viz.

Hour Circles, and *Azimuths.*

Hour Circles are great Circles of the Sphere, which meet together in the Poles of the World, and croſs the Æquinoctial at Right Angles; of which the Meridian (or outward Circle in this Figure) is the hour Circle of 12, the ſtreight line P Q S, which repreſents the Axis of the World, is alſo the Hour-circle of Six, and all the reſt of the Hour-circles are drawn from Pole to Pole between them, as the Circle P A S repreſents the Hour-circle of 8 and 4 a Clock, and ſo of all the reſt, which are 12 in number, repreſenting the 24 hours of the day and night being taken round the Globe or Sphere.

Azimuths are alſo Great Circles of the Sphere, meeting together in the *Zenith* and *Nadir* points, and fall upon, or interſect the Horizon at right Angles; as the Hour-circles do the Æquinoctial. Of theſe Circles, the outermoſt Circle of this Figure repreſents the North and South Azimuth; and the line Z Q N the Azimuth of Eaſt and Weſt, and is commonly called the *Prime Vertical Circle.* And all other circles drawn through the *Zenith* and *Nadir* points, and cutting the Horizon at right Angles, are intermediate Azimuths between the Eaſt and Weſt, and the North or South Points. As in the Figure, the Circle Z B N is an intermediate Azimuth between the South and the Weſt, it being 40 deg. diſtant from O the South point.

Every Circle of the Sphere hath its proper Poles, which are always 90 deg. diſtant from it in all parts.

So in the former Figure Z the Zenith, and N the Nadir points, are the Poles of the Horizon, they being 90 deg.

diſtant from O the South point, from Q the Weſt point, and from H the North point of the Horizon.

Alſo Q is the Pole of the Meridian Circle H Z O N, it being 90 deg. diſtant therefrom in all parts.

Again P and *S*, the North and South Poles of the World, are alſo the Poles of the Æquinoctial Circle, they being removed therefrom on either ſide 90 deg.

But the Pole of the Hour-circle P A S is at C, and the Pole of the Azimuth Circle Z B N is at D, and how to find theſe Poles, and alſo the Poles of any oblique Circles, ſhall be diſcovered in divers places of the following diſcourſe, where there is often occaſion for the finding of them.

Note, *And whereas throughout this Book there is continual mention made of Degrees and Minutes, know, that a Degree is the* 360 *part of any Circle, each of which degrees is ſuppoſed to be divided into* 60 *parts called Minutes, ſo that* 45 *min. is three quarters of a degree,* 30 *min. half a degree, and* 15 *min. one quarter of a degree,* &c.

Theſe are ſuch *Aſtronomical Elements*, as I conceive, moſt neceſſary for the underſtanding of that which follows; It reſteth now that I ſhew how to perform two or three *Aſtronomical Concluſions* Geometrically, without which the knowledge of making of a Dial will be of little validity; for to what purpoſe will a Dial ſerve without it be rightly placed? Or how can you make a Dial for any appointed place, without you firſt know the poſition or ſituation thereof? And to theſe purpoſes are the following Concluſions ſubſervient.

And becauſe it is requiſite to know at all times of the Year, What declination the Sun hath from the Æquinoctial either Northward or Southward, I have therefore at the end of this Introduction, inſerted two Tables, the one ſhewing the Suns Declination *every day in the year. And the other a Table ſhewing the* Latitudes *of all the Principal Cities and Towns in* England, Scotland *and* Ireland.

PROBL.

PROBL. IX.

Having the Latitude *of the* Place, *the* Altitude *of the* Sun, *and the* Day of *the* Month *given, to find the* Hour *of the* Day, *and* Azimuth *of the* Sun.

LEt the Place be *London*, whoſe Latitude is 51 deg. 32 min.---- Let the Suns *Altitude* be 45 deg.---- And let the Day of the Month be the 11*th.* of *May*, at which time, by the following *Table*, the *Suns Declination* is 20 deg. 20 min. North.

Firſt, Deſcribe the Circle H Z O N, repreſenting the Meridian of the Place; ---- Croſs it at right Angles with the two Diameters H Q O, for the Horizon, and Z Q N for the *Prime Vertical* Circle, or *Azimuth* of Eaſt and Weſt.

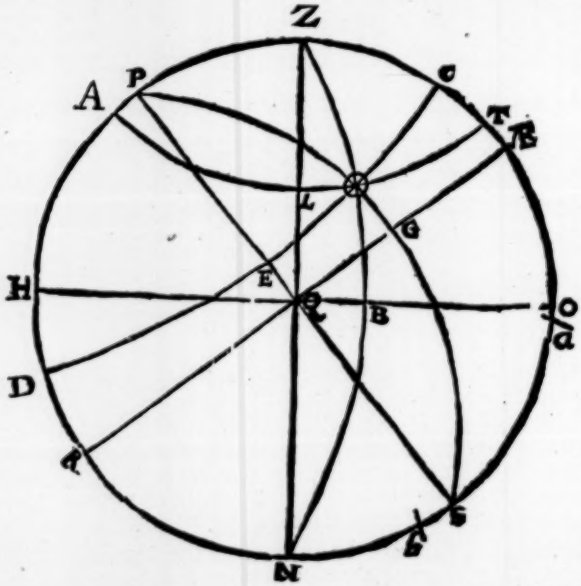
Secondly, Take 51 deg. 32 min. the Latitude of the Place, out of your Line of Chords, and ſet it from H to P the North, and from O to *S* the South Pole; and draw the line P Q *S*, for the Axis of the World. And becauſe the Æquinoctial Circle is, in all parts, diſtant from the Poles of the World, 90 deg. take 90 deg. of your Chord, and ſet them from P to Æ, and from *S* to æ, and draw the line Æ Q æ, for the Æquinoctial Circle.

Thirdly, The Suns Altitude given being 45 deg, Take 45 deg. from your Chord, and ſet them from H to A, and from O to T; and lay a Ruler either from H to T, or from O to A, and the Ruler will croſs the Prime vertical Circle in L, through which point the Circle of the Suns Altitude muſt be drawn, and for the drawing of it, you have three points, A, L and T, wherefore by the *6th.* Probleme beforegoing you may find its centre, which will always be in the Prime Vertical Circle Z Q N, extended.

Fourthly, The Suns Declination for the day propoſed, (*viz.* the 11*th.* of *May*) being 20 deg. 20 min. Northward, therefore take 20 deg. 20 min. out of your line of Chords

Chords, and ſet them from Æ to C, and from æ to D, towards P the North Pole, becauſe the Declination was North, otherwiſe it ſhould have been ſet towards *S* the South Pole. ---- Then laying a Ruler either from Æ to D, or from æ to C, it will in both caſes cut the Axis of the World in E, through which point the Parallel of the Suns declination for that day muſt be deſcribed, and for the drawing of it, you have three Points D, E and C, whoſe Centre will always be in the Axis of the World S Q P extended, and may be found by the former Sixth Probleme.

Fifthly, Obſerve in your Scheme, where the Parallel of Altitude A L T, and the Parallel of Declination D E C, do croſs each other. which will be at the point ⊙, and that is the place of the Sun at the time of the Queſtion.



Sixthly, By the forementioned *6th.* Probl. draw an Hour-circle

circle through the three points P ⊙ and *S*, whoſe centre will always be in the Æquinoctial line extended, if need be; alſo, through the Points Z ⊙ and N, draw an Azimuth Circle, whoſe centre will always be in the Horizon extended when need requires.

Theſe two Circles being thus drawn, your Scheme is prepared for the finding both of the *Hour* and *Azimuth* in this manner.

I. *For the* HOUR.

Lay a Ruler to P, the Pole of the World, and G the point where the Hour-circle croſſeth the Æquinoctial, and the Ruler will cut the Circle in *a*. So the diſtance from *a* to Æ being meaſured upon the line of Chords, will be found to contain 41 deg. 48 min. which is the *Hour* of the day, counted from Noon, which reduced into Time (by allowing 15 deg. to an hour, and 4 deg. to one minute of time) will be two hours, 47 minutes, that is either 47 minutes after 2 in the After-noon, or 13 minutes after 9 in the Fore-noon.

II. *For the* AZIMUTH.

Lay a Ruler to Z the Zenith, and to B the point where the Azimuth Circle croſſeth the Horizon, and the Ruler will cut the Meridian Circle in the point *b*, ſo the diſtance *b* O, being meaſured upon the Line of Chords, will be found to contain 62 deg. 8 minutes. And ſuch is the Suns *Azimuth* from the *South* part of the *Meridian*. ---- Or the diſtance N *b*, being meaſured upon the Chords, will be found to contain 27 deg. 52 min. which is the Suns diſtance or *Azimuth*, from either *Eaſt* or *Weſt*, according to the time of the day.

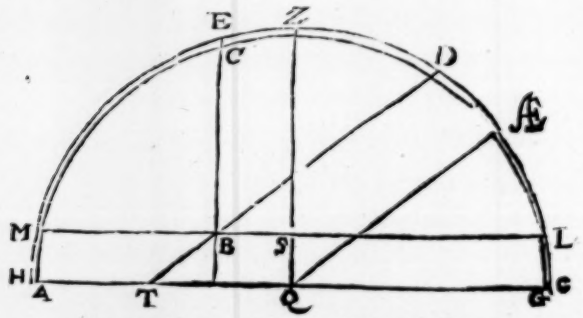
Thus by one and the ſame Projection of the Sphere, you have found both the *Hour* and the *Azimuth*, and many

many other *Concluſions Aſtronomical* might be wrought by this way of Projection, which I have more fully ſhewed in my *Geometrical Exerciſes*, now lately publiſhed. But ſeeing that the *Azimuth* is of ſuch frequent uſe in Dialling, that nothing can be done to purpoſe without it, and that in this way of Projection, ſometimes the centres of the Circles will be very remote, I will here ſhew you another Geometrical way, whereby you may find the *Azimuth* at any time, and in any place, by ſtreight Lines, which will be ſome light and eaſe to the Practitioner, that ſo he may compare one Way with the other in caſe of any doubt, which will be a good confirmation of his Work.

Another way to find the Azimuth.

LEt the given Latitude be 51 deg. 32 min.
The Declination North, 20 deg.
The Suns Altitude 12 deg.
And let the Suns Azimuth be required.

Firſt, Upon the centre Q, deſcribe the Semi-circle H Z O for half the Meridian, and upon Q, raiſe the Perpendicular Q Z, ſois Z the Zenith.



Secondly, Set (by help of your Line of Chords) 51 deg. 32 min. the Latitude of the place, from Z to Æ, and draw Æ Q for the Æquinoctial.

Thirdly,

Thirdly, Set 20 deg. the Suns Declination, from Æ towards Z, to the Point D, (being it is North) and draw the Line D T parallel to Æ Q, ſo is D B T the *Parallel* of the *Suns Declination.*

Fourthly, Set 12 deg. the Suns Altitude given, from O to L, and from H to M, and draw the Line M L, for the *Parallel of Altitude.*

Fifthly, Take in your Compaſſes, half the length of the Parallel of Altitude S L, or S M, and with that diſtance upon Q, deſcribe the innermoſt Semicircle A C G.

Sixthly, From the point B, which is where the Parallel of Declination, and the Parallel of Altitude do interſect, erect the Perpendicular B C, till it touch the innermoſt Semicircle.

Laſtly, Lay a Ruler from Q to C, and it will cut the outermoſt Circle in E, ſo ſhall H E meaſured upon the Line of Chords, be 72 deg. 52 min. the Suns Azimuth from the North part of the Meridian.

E Z ſhall be 17 deg. 8 min. the Azimuth from Eaſt or Weſt. And,

E O ſhall be 107 deg. 8 min. the Azimuth from the South part of the Meridian.

Having made this fair Preparative, I will here inſert the two fore-mentioned neceſſary Tables *of the* Suns Declination, *and* Latitudes *of Places; and then proceed to the* Art of Dialling, *the thing chiefly in this place intended.*

A Table of the Suns Declination.

days	January d.	mi.	Februar. d.	mi.	March d.	mi.	April d.	mi.	May d.	mi.	June d.	mi.
1	21	44	3	46	3	24	8	36	18	5	23	12
2	21	33	13	26	3	0	8	58	18	20	23	16
3	21	23	13	5	2	37	9	20	18	35	23	19
4	21	13	12	45	2	13	9	42	18	50	23	22
5	21	2	12	25	1	49	10	3	19	4	23	25
6	20	50	12	4	1	25	10	24	19	18	23	27
7	20	38	11	43	1	1	10	45	19	31	23	29
8	20	26	11	21	0	38	11	0	19	44	23	30
9	20	13	11	0	0	14	11	27	19	57	23	31
10	20	0	10	38	0 South	10	11	47	20	10	23	32
11	19	46	10	16	0 North	33	12	7	20	22	23	31
12	19	32	9	54	0	57	12	28	20	34	23	31
13	19	18	9	32	1	21	12	48	20	45	23	30
14	19	3	9	10	1	44	13	7	20	56	23	29
15	18	48	8	48	2	8	13	27	21	7	23	28
16	18	33	8	25	2	31	13	46	21	17	23	26
17	18	17	8	3	2	54	14	5	21	27	23	23
18	18	2	7	40	3	18	14	24	21	37	23	20
19	17	45	7	17	3	41	14	42	21	46	23	17
20	17	28	6	54	4	5	15	1	21	55	23	14
21	17	11	6	31	4	28	15	19	22	4	23	10
22	16	54	6	8	4	51	15	37	22	12	23	6
23	16	36	5	45	5	14	15	54	22	20	23	1
24	16	18	5	21	5	37	16	12	22	27	22	55
25	16	0	4	58	6	0	16	29	22	34	22	50
26	15	42	4	34	6	22	16	46	22	41	22	44
27	15	23	4	11	6	45	17	2	22	47	22	37
28	15	4	3	47	7	7	17	18	22	53	22	31
29	14	45			7	30	17	34	22	58	22	23
30	14	26			7	52	17	50	23	3	22	16
31	14	6			8	14			23	8		

A Table of the Suns Declination.

Days	July d.	mi.	August d.	mi.	Sept. d.	mi.	Octob. d.	mi.	Novem d.	mi.	Decem. d.	mi.
1	22	8	15	12	4	24	7	15	17	40	23	9
2	22	0	14	54	4	2	7	38	17	56	23	13
3	21	51	14	36	3	38	8	0	18	12	23	17
4	21	42	14	17	3	15	8	22	18	28	23	20
5	21	32	13	58	2	52	8	45	18	43	23	23
6	21	22	13	39	2	29	9	7	18	58	23	26
7	21	12	13	20	2	5	9	29	19	13	23	28
8	21	2	13	1	1	42	9	51	19	27	23	30
9	20	51	12	41	1	19	10	13	19	41	23	31
10	20	40	12	21	0	North 55	10	35	19	55	23	31
11	20	28	12	1	0	South 32	10	56	20	8	23	31
12	20	16	11	41	0	8	11	18	20	21	23	31
13	20	4	11	21	0	16	11	39	20	34	23	29
14	19	51	11	0	0	39	12	0	20	46	23	27
15	19	38	10	39	1	3	12	21	20	58	23	25
16	19	25	10	18	1	26	12	41	21	9	23	22
17	19	12	9	57	1	50	13	2	21	20	23	19
18	18	58	9	36	2	13	13	22	21	31	23	16
19	18	43	9	15	2	37	13	42	21	41	23	12
20	18	29	8	53	3	0	14	2	21	50	23	7
21	18	14	8	31	3	25	14	21	22	0	23	2
22	17	59	8	9	3	47	14	41	22	9	23	57
23	17	44	7	47	4	10	15	0	22	17	22	51
24	17	28	7	25	4	33	15	19	22	15	22	44
25	17	12	7	3	4	57	15	37	22	33	22	37
26	16	56	6	41	5	20	15	55	22	40	22	30
27	16	39	6	18	5	43	16	1	22	46	22	22
28	16	22	5	56	6	6	16	3	22	52	22	14
29	16	6	5	33	6	29	16	49	22	58	22	5
30	15	48	5	10	6	52	17	6	23	4	22	56
31	15	30	4	47			17	28			21	

A TABLE *of the* Names *and* Latitudes *of the Pincipal* Cities, Towns *and* Iſlands *in and about* Great Brittain *and* Ireland.

England.	D.	M.
BEdford	52	8
Barwick	55	54
Briſtol	51	27
Buckingham	52	0
Cambridge	52	12
Canterbury	51	17
Carliſle	55	0
Chicheſter	50	48
Cheſter	53	16
Colcheſter	51	58
Derby	52	58
Dorcheſter	50	40
Durham	54	50
Exceſter	50	43
Gilford	51	12
Glouceſter	51	53
Hartford	51	49
Hereford	52	7
Huntington	52	19
Ipſwich	52	8
Kendal	54	23
Lancaſter	54	10
Leiceſter	52	40
Lincoln	53	14
London	51	32
Northampton	52	14
Norwich	52	41
Nottingham	53	0
Oxford	51	46

England.	D.	M.
Reading	51	28
Saliſbury	51	4
Shrewſbury	52	47
Stafford	52	52
Stamford	52	38
Truero	50	30
Warwick	52	20
Wincheſter	51	3
Worceſter	52	14
York.	53	58

Wales.	D.	M.
ANgleſey	23	28
Barmonth	52	50
Brecknock	52	1
Cardigan	52	12
Carmarthen	51	56
Carnarvan	53	16
Denbigh	53	13
Flint	53	17
Landaff	51	35
Monmouth	51	51
Montgomery	51	56
Pembroke	51	46
Radnor	52	19
St. David.	52	0

Iſlands

Islands.	D.	M.
Arnsey	49	30
Jersey	49	12
Limdy	51	22
Man	54	24
Portland	50	30
Wight	50	39

Scotland.	D.	M.
Berdean	57	32
Dunblain	56	21
Dunkel	56	48
Edenburgh	55	56
Glascow	55	52
Kinsaile	57	44
Orkney	60	6
St. Andrews	56	39
Skyrasslin	58	36
Sterling.	56	12

Ireland.	D.	M.
Antrim	54	38
Arglas	54	10
Armah	54	14
Caterlagh	52	41
Clare	52	34
Corke	51	53
Droghedagh	53	38
Dublin	53	20
Dundalke	53	52
Galloway	53	2
Youhall	51	53
Kenny	52	27
Kildare	53	0
Kings Town	53	8
Knockfergus	54	37
Kynsale	51	41
Lymerick	52	30
Queens Town	52	52
Waterford	52	9
Wexford	52	18

The End of the Introduction.

The

The ART of DIALLING

Geometrically performed,

By Projecting of the Circles of the *Sphere* upon the *Plain* it ſelf.

The Firſt Part.

CHAP. I.

Of the ſeveral ſorts of Plains *upon which* DIALS *are uſually made.*

DIALS may be made upon any plain Superficies, and all plain Superficies are poſited in one or other of theſe three poſitions, *viz.* either *Parallel*, *Perpendicular*, or *Oblique* to the *Horizon* of the Place wherein the Plain is ſeated, and all the Hour-lines drawn upon any Plain, are great Circles of the Sphere, which being projected upon a plain Superficies, become ſtrait Lines.

Now

Now the Art of Dialling conſiſteth chiefly in the finding out of theſe Lines, and their true diſtances each from other, the which do continually vary, according as the Plains upon which they are deſcribed or projected, are ſcituated in reſpect of the *Horizon* of the place.

Of theſe Plains there are but three Varieties, *viz.*

1. *Parallel* to the Horizon, as is *Horizontal* the which I call *Vertical*) Plain only.

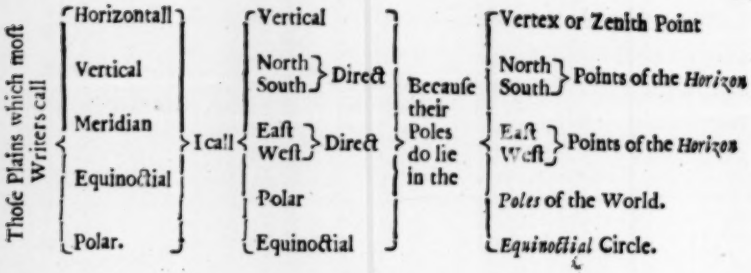
2. *Perpendicular* to the Horizon, and ſuch are all erect Plains: which be either Direct (*North* & *South*; *Eaſt* & *Weſt*) As Or *Declining*.

3. *Reclining* from the *Zenith*, or Inclining to the *Horizon*. and theſe are either Direct (*North*, *South* *Reclining*; *Eaſt*, *Weſt* *Inclining*) Or Declining (*Reclining*, *Inclining*)

Now in the making of particular *Dials*, which are in number 25, I reduce them to 17, by ſupplying the *Inclining Plains* from their oppoſite *Recliners*, as being indeed the ſame.

And to avoid miſtakes, which may poſſibly ariſe by comparing my *Examples* with other *Authors*, or others with mine, You are to take notice, that I denominate all my *Plains* from the ſight (or the Poſitions) of their *Axis* in the Heavens, and not from the Circles of the Sphere in which they lie. Therefore take notice, That

Thoſe



Again,

All leaning Plains whether Direct or Declining, whoſe upper Faces behold the *Zenith*, I call *Recliners*; and the nether, or under Faces of them, which reſpect, or look down to the *Nadir*, I call *Incliners*.

This diſtinction being made, the Plains of all which Examples following are thus denominated.

1. *Vertical* or *Horizontal.*
2. *South* and *North* Direct.
3. *Eaſt* and *Weſt* Direct.
4. *South* and *North*, declining { *Eaſt* Or, *Weſt*
5. *Eaſt* and *Weſt* Direct { *Reclining* Or, *Inclining.*
6. *Equinoctial*, Or *South* Reclining or Inclining to the *Pole.*
7. 8. } *South* direct Reclining or Inclining { leſs more } than the *Pole.*
9. *Polar*, Or *North* Reclining or Inclining to the *Equinoctial.*
10. 11. } *North* direct Reclining or Inclining { leſs more } than the *Equinoctial.*
12. *Equinoctial*, Or *South* Declining *Eaſt* or *Weſt* Reclining to the *Pole.*

13. *South*

13. } *South* declining *East* or *West* { above } the *Pole.*
14. } Reclining or Inclining { under }

15. *Polar* or *North* declining *East* or *West*, Reclining or Inclining to the Equator:

16. } North declining East or West { above } the Intersection
17. } Reclining or Inclining { under } of the Meridian and Equator.

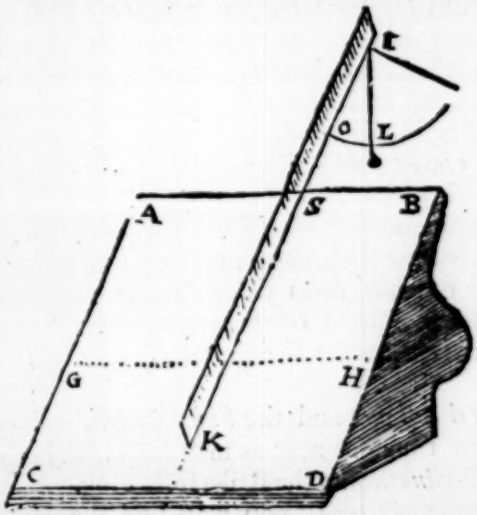
Thus are the several Plains denominated, I shall now shew how the Situation of any Plain may be attained, either in respect of its *Declination* or *Reclination.*

CHAP. II.

How to find the Reclination *and* Declination *of any Plain.*

I. *For the* Reclination.

THe *Reclination of a Plain*, is the Arch of that *Vertical Circle* or *Azimuth*, which is perpendicular to the *Reclining Plain*, or that *Azimuth*, in which the *Pole* of the *Reclining Plain* lieth, comprehended between the *Zenith* of the place, and the *Reclining Plain.*



F

To find which, let A B C D be a *Reclining Plain*, draw first thereon by help of a *Ruler* and *Quadrant*, a line G H parallel to the *Horizon* of the place, which shall be the *Horizontal Line of the Plain*, and cross it at right Angles with another right line K S, for the *Vertical Line*

Line of the Plain; *to this Vertical Line* K S, apply a ſtreight Ruler K I, and to that end of it, which lieth clear of the Plain as I, apply a Quadrant as O L I; having a thread and plummet hanging from the Centre at I, then ſee what number of degrees of the Quadrant are contained between O and L, for ſo much doth the Plain *Recline* from the *Zenith*.

II. *For the* Declination.

The *Declination of a Plain*, is an Arch of the *Horizon* comprehended between the *Pole of the Plain*, and the *Meridian of the Place*. Or it is the diſtance of the *Plain it ſelf*, from the prime *Vertical Circle*, or *Azimuth* of *Eaſt* and *Weſt*.

To find out the Declination of any Plain, there are required two Obſervations to be made by the Sun at the ſame inſtant of time. The firſt of the *Horizontal diſtance of the Sun from the Pole of the Plain*, and Secondly, *Of the Suns Altitude*.

1. To find the Suns *Horizontal diſtance from the Pole of the Plain*. Apply one edge of a Quadrant to the Horizontal line of your Plain, ſo that the other may be perpendicular to it, and the limb of the Quadrant may be towards the Sun, and hold the whole Quadrant Horizontal (as near as you can conjecture.) Then holding up a thread and plummet at full liberty, ſo that the ſhadow of the thread may paſs both through the Centre and Limb of the Quadrant, obſerve then the degrees cut by the ſhadow of the Thread, and number them from that ſide of the Quadrant that ſtandeth ſquare or perpendicular to the Plain: For thoſe degrees are the *Horizontal diſtance* required.

2. This *Horizontal diſtance* and the *Suns Altitude* being obſerved at the ſame time (as near as may be) will help you to the *Plains Declination* by the Rules following.

Firſt, By having the *Altitude*, you may find the *Azimuth*,

muth by the two laſt *Problemes* of the *Introduction*. Then by comparing the Azimuth and this Diſtance together, you may find the *Plains Declination* in this manner.

When you make your Obſervations of the Suns *Horizontal diſtance*, mark whether the ſhadow of the thread fall between the *South*, and that ſide of the Quadrant which is perpendicular to the plain.

1. If the ſhadow fall between them, the *Azimuth* and *Diſtance* added together, do make the *Declination of the Plain*, and in this caſe the *Declination* is upon the *ſame coaſt* whereon the Suns *Azimuth* is.

2. If the ſhadow fall not between them, then the difference between the *diſtance* and *Azimuth* is the *Plains declination*; and if the *Azimuth* be the greater of the two, then the Plain declines to the ſame Coaſt whereon the Sun is; but if the diſtance be the *greater*, then the Plain declines to the *contrary* Coaſt.

And here note, that the Declination thus found is always accounted from the *South*, and that all Declinations are counted from either *South* or *North*, towards either *Eaſt* or *Weſt*, and muſt never exceed 90 degrees.

1. If therefore the degrees of declination do exceed 90, you muſt take the reſidue of that number to 180, and that ſhall be the *Plains declination* from the *North*.

2. If the degrees of declination exceed 180, then the exceſs above 180 degr. gives the *Plains declination* from the *North* towards that Coaſt, which is contrary to the Coaſt whereon the Sun is.

I. *Of the Vertical Dialling.*

CHAP. III.

How to draw the Hour-lines upon a Vertical (*commonly called* Horizontal) *Plain.*

I Call this Plain *Vertical*, becauſe the Pole thereof is in the *Zenith* or *Vertex* of the Place, although the Plain it ſelf lie in the Plain of the *Horizontal Circle*. And I not only denominate this, but all the other Plains following, by that part of the Sphere in which the Poles and not the Plains themſelves lie. But howſoever the Plain be termed, whether *Vertical* or *Horizontal*, the making of the Dial is ſtill the ſame: And may be made in any known Latitude by the precepts following.

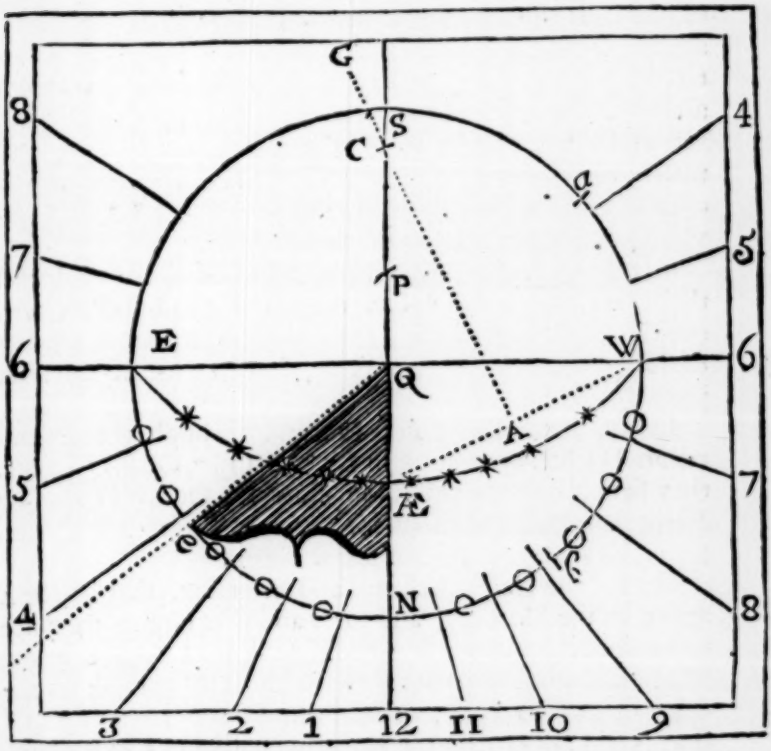
Example, Of a Vertical *or* Horizontal *Plain in the Latitude of* London, *which is* 51 *deg.* 32 *min.*

Firſt, Draw a Circle E S W N, which Circle let repreſent your *Vertical Plain*, croſs it in the middle thereof at right Angles with the two Diameters, *viz.* S Q N, for the Meridian, and Hour-line of 12, and E Q W for the Prime *Vertical* or Hour-line of 6.

Secondly, Becauſe the Latitude of the place is 51 deg. 32 min. take 51 deg. 32. min. out of your Line of Chords, and ſet that diſtance from S to *a*, and from W to *b*.

Thirdly, Lay a Ruler from E to *a*, and it will cut the Meridian Line S N, in the point P, which point P is the Pole of the World: And a Ruler laid from E to *b*, will cut the Meridian in the point Æ, ſo is Æ the point where the Æquinoctial croſſeth the Meridian; and thus have you three points, *viz.* E, Æ, and W, through which you muſt draw

A Vertical or Horizontal Dial for the Latitude of London, 51 *deg.* 32 *min.*



draw the Æquinoctial Circle E Æ W, whoſe centre will always be in the Meridian Line S N. So that you may eaſily find it, as hath been before taught, and in this manner alſo. Draw the Line Æ W, which divide in two equal parts in the point A, upon which point A, raiſe the perpendicular A C, cutting the Meridian S N, in the point C, which is the centre of the Æquinoctial Circle E Æ W, upon which point, and the diſtance C Æ, you may deſcribe it.

Fourthly,

Fourthly, Divide the Semicircle E N W, into 12 equal parts at the points ⊙ ⊙ ⊙, *&c.* beginning at the point N, and ſetting ſix on either ſide thereof. The Semicircle may eaſily be divided into 12 parts in this manner; for 60 deg. of the Line of Chords will divide it into three equal parts, and 30 deg. will divide each of them into two, that is, into 6 equal parts, and 15 deg. is the half thereof, which is a twelfth part of the Semicircle.

Fifthly, Lay a Ruler to Q, the centre of the Plain, and upon every of theſe points ⊙ ⊙ ⊙, and the Ruler will cut the Æquinoctial E Æ W, in the points * * *, &c. dividing that into 12 unequal parts.

Sixthly, A Ruler laid to P, the Pole of the World and the ſeveral points * * *, &c. upon the Æquinoctial, will cut the Circle repreſenting the plain in the points]]], &c. dividing the Semicircle E N W, into 12 other unequal parts.

Laſtly, From the point Q, and through the ſeveral points]]], &c. draw ſtraight Lines, as Q] 7, Q] 8, Q] 9, &c. they ſhall all be the true Hour-lines for ſuch a *Vertical* or *Horizontal Plain.* Namely, for twelve of them, that is, from Six in the Morning, till Sill Six at Night.

But for the Hours before, and after Six, that is, for 4 and 5 in the Morning, and for 7 and 8 at Night, they are to be drawn by extending the Hour-line of 7 and 8 in the Morning through the centre Q, and drawing them on the other ſide of the Plain, ſo ſhall they be the Hours of 7 and 8 at Night: ——Alſo the Hour-lines of 4 and 5 in the Evening, being drawn through the centre Q, will become the Hour-lines of 4 and 5 in the Morning.

For the Stile of this Dial, take 51 deg. 32 min. the Latitude of your place, out of your Line of Chords, and ſet them from N to *e*, upon the Circle of the Plain, ſo ſhall a Line drawn from Q through *e*, be the *Axis* or *Stile of the Dial*, which may be a thin plate of Braſs, cut exactly to the quantity of the Angle *e* Q N. 51 deg. 32 min. and ſet per-

perpendicularly upon the Line of 12, or the Meridian S Q N, and thus is your Dial finiſhed.

If into this, or any of the following Dials, you have a deſire to inſert the Half Hours and Quarters, you may put them in by the very ſame means, as you did the whole Hours, but then you muſt divide the Spaces between every of the points ⊙⊙ into two equal parts for the Half, and into 4 equal parts for the Quarters of Hours, and proceed with putting on of them in all reſpects as you did with the whole Hours.

II. *Of Upright or Erect Plains.*

CHAP. IV.

THoſe Plains are ſaid to be *Erect* or *Upright*, which ſtand perpendicular to the *Horizon* of the place, whoſe Vertex or upper part tendeth to the *Zenith*, and their lower part to the *Nadir*, and ſuch are the Walls of Steeples, Churches, Houſes, or the like, againſt which (for the moſt part) Dials are made.

Of theſe *Upright* or *Erect Plains* there are two ſorts, *viz.* *Direct* and *Declining*.

Thoſe Erect or Upright Plains are ſaid to be Direct, which do directly behold either the true Eaſt, Weſt, North, or South points of the *Horizon*, or whoſe Poles do lie directly in either of them, and theſe Plains are called *Erect Direct Plains*.

Thoſe *Erect* or *Upright Plains* are ſaid to decline, which do not lie in, or directly behold any of theſe points, but are ſituate under ſome other *Azimuth*, as *South-Eaſt*, *North-Weſt*, *North-Eaſt*, &c. and theſe *Plains* are called *Erect* or *Upright Declining Plains*. Of both which ſorts I ſhall give you Examples. And

I. *Of*

I. *Of Upright, or Erect Direct Plains.*

CHAP. V.

How to draw the Hour-lines upon a Direct South Plain.

THat Plain is called, by me, a *Direct South Plain*, which lieth in the prime Vertical Circle, or East and West *Azimuth*, and whose Pole is in the South part of the Meridian, the making whereof differeth nothing from that going before. Only for the height of the Stile, instead of the Latitude you must take the Complement thereof.

Example, Of a Direct South Plain, *in the Latitude of* London, 51 *deg.* 32 *min.*

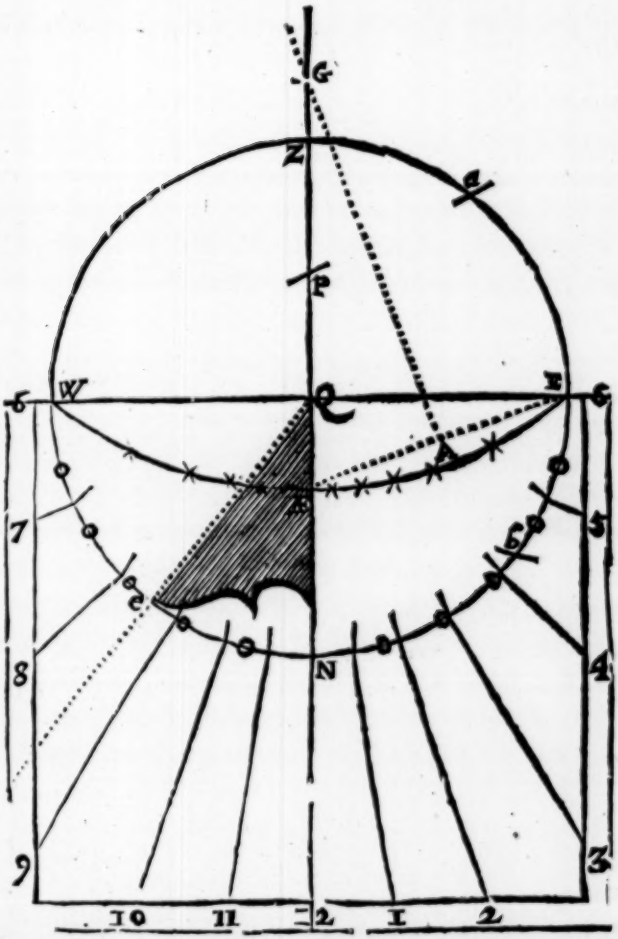
First, Draw a Circle Z E W N, representing an upright Direct South Plain, cross it at right Angles with the Diameters Z Q N for the Meridian, or Hour-line of 12, and W Q E for the prime Vertical Circle, or Hour-line of Six.

Secondly, Out of your Line of Chords take 38 deg. 28 min. (which is the complement of the Latitude of the place) and set that distance upon the Dial-plain, from Z to *a*, and from E to *b*, and from N to *e*.

Thirdly, Lay a Ruler from W to *a*, it will cut the Meridian Z N, in the point P, the Pole of the World; and a Ruler also laid from W to *b* will cut the Meridian in Æ, so is Æ the point through which the Æquinoctial must pass; and for the drawing of it you have three points given, *viz.* E, Æ, and W, and the Centre will alwayes be in the Meridian Line Z N, (extended if need be.) The Centre you may find by the Geometrical way taught at the beginning of the Book. Or thus, draw the Line E Æ, and divide

it

An Erect Direct South Plain.



it in two equal parts in A, upon A erect the perpendicular AC, extending it till that and the Meridian Line concur in G, ſo is G the centre of the Æquinoctial Circle E Æ W.

Fourthly, Divide the Semicircle E N W into 12 equal parts, at the points ⊙ ⊙ ⊙, *&c.*

Fifthly, lay a Ruler to Q, and each of these points ⊙ ⊙ ⊙, and the Ruler will cross the Æquinoctial Circle in the points * * *, *&c.* dividing that into 12 unequal parts.

Sixthly, Lay a Ruler to P, (the Pole of the World) and every of the marks * * *, *&c.* and the Ruler will cross the circle of the Plain in the points | | |, *&c.*

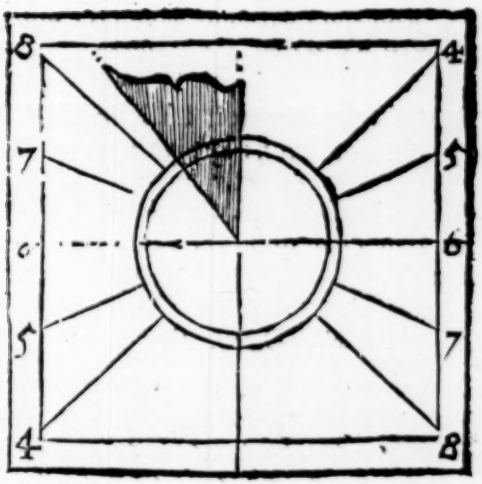
Lastly, If through the Centre Q, and the respective points | | |, *&c.* You draw Right Lines, they shall be the true Hour Lines of an *Erect Direct South Plain.*

For the Stile, take 38 deg. 28 min. the complement of the Latitude of your Place, out of the Line of Chords, and set them from N to *e*, drawing the Line Q *e* for the Axis of the Stile, which must hang directly over the Meridian, or Hour-line of 12, and must point downwards towards the South Pole, because the Plain beholds the South part of the Meridian.

In making this Dial you have made two Dials, for the *Erect Direct North Dial* is but the back-side of the South, it lying in the same Prime Vertical Circle, only as this beholdeth the South part of the Meridian, and hath the South Pole elevated above it, the other beholdeth the North part of the Meridian, and hath the North Pole elevated above it, and as the Meridian Line Z Q N in the South Dial representeth the 12 a Clock Hour-line at Noon, the back-side thereof (namely the North side) representeth the Hour-line of 12 at Midnight, and therefore is not expressed, neither the Hour-lines of 9, 10, 11 at Night, or of 1, 2, 3 in the Morning, the Sun to us never being above the Horizon at those Hours: wherefore the North Dial is only capable of receiving these Hours, namely, 4, 5, 6, 7 and 8 in the Morning, and of 4, 5, 6, 7, and 8 at Night, and (in this Latitude) not of all them neither; for it will never shine upon this Plain at 8 in the Morning, nor at

4 in

An Erect Direct North Plain.



4 in the Afternoon, but it is beſt to put them on, as in the Figure above, that thereby you may know how much it is paſt 7 in the Morning, and how much it wants of 5 in the Afternoon.

CHAP. VI.

How to draw the Hour-lines upon an Erect, Direct, Eaſt, *or* Weſt *Plain.*

I Call that an *Eaſt* or *Weſt Plain*, which lies in the *Meridian* of the place, and whoſe Poles lie in the prime Vertical Circle, or *Azimuth* of *Eaſt* or *Weſt*.

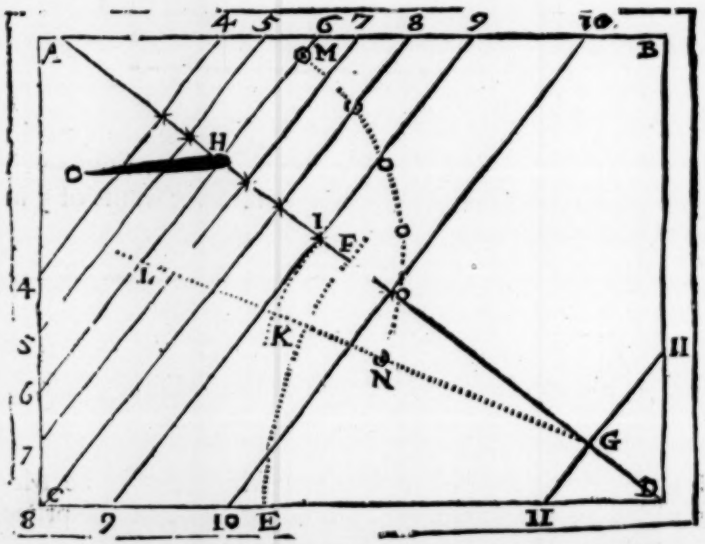
Now foraſmuch as the Plain lieth in the very Meridian Circle, in which alſo the two Poles of the World are

ſeated, the Plain muſt neceſſarily paſs through both theſe Poles, and ſo neither of them can have any Elevation above it; wherefore the Hour-lines in theſe Dials muſt be parallel to one another, and conſequently parallel to the Axis of the World. And the Dial muſt have no Centre: However the Dial may be drawn as followeth.

Example, Of an Eaſt Direct Dial, *in the Latitude of* London 51 *deg.* 32 *min.*

Let A B C D, be a Dial plain, upon which you would draw a *Direct Eaſt Dial*, upon the point D, if it be an Eaſt Dial; or upon the point C, if it be a Weſt Dial; with the

An Erect, Direct, Eaſt Dial.



Radius (or 60 deg.) of your Line of Chords, deſcribe an obſcure Arch of a Circle E F, then from your Chord take 38 deg.

38 deg. 28 m. the Complement of the latitude of the place, (which is alſo the height or elevation of the Æquinoctial) and ſet them from E to F, and draw the line D F quite through the Plain. Then, that you may proportion your ſtile to your Plain, ſo that you may bring on all the hours from Sun Riſing to 11 a Clock, aſſume two points in the Line F D, one towards the end D (as the point G) for the Hour-line of 11, and another at H, for the Hour-line of 6, and through the points G and H, draw the lines 11 G 11, and 6 H 6, perpendicular to the Æquinoctial Line D F. This done, upon the point G, with 60 deg. of the Line of Chords, deſcribe an obſcure Arch of a Circle I K, and ſet thereon 15 deg. of your Line of Chords from I to K, and draw the Line G K, to cut the Line 6 H 6 in the point L. ſo ſhall L H be the height of the perpendicular ſtile proportioned to this Plain.

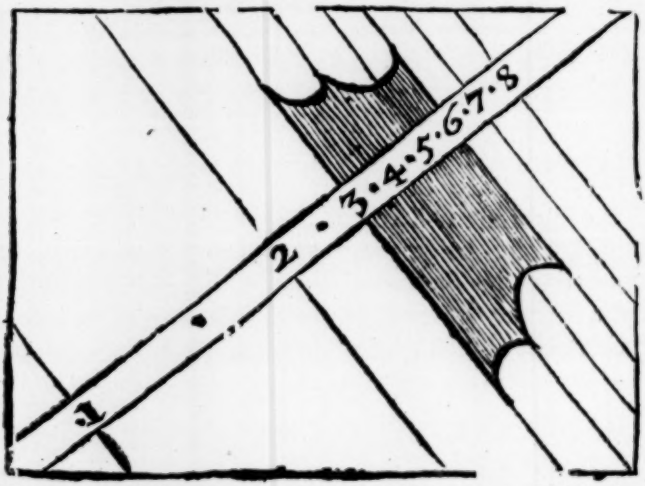
Now for the drawing of the Hour-lines, ſet one foot of the Compaſſes (opened to 60 deg. of the Chord) in L, and with the other deſcribe the Arch of a Circle M N, betwixt the Hour-line of 6, and the Line G L. Which divide into 5 equal parts in the points ⊙ ⊙ ⊙ ⊙ ⊙, and a Ruler laid from the point L to each of theſe points ⊙ ⊙ ⊙, *&c.* will cut the Æquinoctial Line H D, in the points * * * * *, through which points draw lines parallel to 6 H 6, as the Lines 7 * 7, 8 * 8, *&c.* and they ſhall be the true Hour-lines of an Eaſt Plain from 6 in the Morning, till 11 before noon, but for the Hours of 4 and 5 in the Morning, you may put them on by ſetting the ſame diſtances upon the Æquinoctial Line before 6, as there is from 6 to 7 and 8, after 6; and through thoſe points draw the Hour-lines of 4 and 5, parallel to the Hour of 6, as you ſee done in the Figure.

Thus is your Dial finiſhed, and in the making of it you have made two Dials, namely a *Weſt Dial as well as an Eaſt*, for it is the ſame in all reſpects. Only whereas the Arch E F, through which the Æquinoctial paſſeth in the

Eaſt

East Dial, was drawn on the right hand of the Plain, in the West it must be drawn on the left hand, and the Hour-lines of 4, 5, 6, 7, 8, 9, 10, and 11, in the Forenoon on the East Dial, must be 8, 7, 6, 5, 4, 3, 2 and 1 in the Afternoon, upon the West Dial, as in the Figure appeareth.

An Erect, Direct, West Dial.



The Stile of the East or West Dials, may be either a strait Pin of the just length of the Line H O, which is equal to H L in the East Dial, fixed in the point H, upon the Hour-line of 6, and exactly perpendicular to the Plain, shewing the Hours by the shadow of the Apex, or very top thereof.

Or, it may be a Plate of Brass of the same breadth with the distance between the Hour-lines of 6 and 3, which Plate must be set perpendicular upon the Hour-line of Six, and so it will shew the Hour by the shadow of the upper edge thereof, as in this West Dial.

These five Dials here described, *viz.* the *Vertical*, the *South*, *North*, *East*, and *West* Erect, Direct, may be made upon a stone cut square in form of a *Die*, which Body is called a Cube.

II. *Of*

II. *Of Upright Declining Plains.*

CHAP. VII.

How to draw the Hour-lines upon a South or North Erect Plain, Declining *either* East *or* West.

THE Upright or Erect Plains, that we have hitherto treated of, are such as did directly behold the four Cardinal or Principal Points of the *Horizon*; namely, the *East*, *West*, *North* and *South* Points. All other Upright Plains are said to *decline*, and their Declination is counted from the East or West, towards either North or South, and these Plains are called South or North Erect Plains declining East or West.

Before the Hour-lines can be drawn upon any of these Plains, two things must be given, and three other things must be found——

The Things given must be,

1. The Latitude of the Place.
2. The Declination of the Plain.

The Things required are,

1. The height of the *Pole* (or *Stile*) above the Plain.
2. The distance of the *Substile* from the *Meridian*, or 12 a Clock Hour-line.
3. The *Plains Difference of Longitude.*

For the finding of these, we must project upon the Plain such Circles of the Sphere (in their true positions) as are requisite for the finding of them, and those Circles are, the *Horizon*, the *Meridian*, and the *Æquinoctial*: which I shall shew how to perform by giving an

Example

Example of a South Erect Plain, *declining* Westward 24 *deg.* 20 *min. in the Latitude of* London 51 *deg.* 32 *min.*

		d.	*m.*
Data	Latitude of the Place	51	32
	Declination *South* West	24	20

		d.	*m.*
Quæsita	Distance of the Substile from the Merid.	18	8
	Height of the Pole (or Stile) above the Plain	34	33
	Plains difference of Longitude	30	00

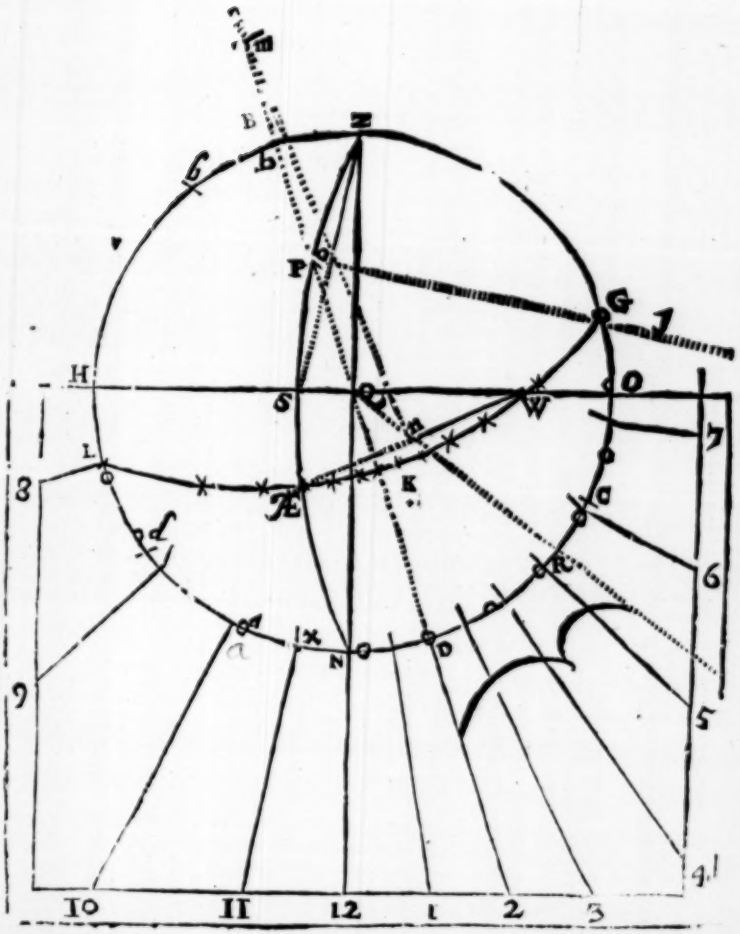
To find which,

First, Describe the Circle Z H N O, representing the declining Plain, cross it at right Angles, with the two Diameters Z Q N, and H Q O, the point Z representing the *Zenith*, and N the *Nadir*, and the line Z Q N, the Vertical or perpendicular-line of the Plain (and Hour-line of 12) and the Line H Q O, is the *Horizontal* Line thereof.

Secondly, Because the Plain declines 24 deg. 20 min. from the South Westward, set 24 deg. 20 min. from N to *a*, and from O to *c*. Then lay a Ruler from Z to *a*, and it will cut the *Horizontal* Line H Q O in S, so is S the South point of the Horizon, through which the *Meridian* must be drawn, and for the drawing of it you have three points, *viz.* Z S and N, and the Centre will always be in the *Horizontal* Line H Q O, extended if need be. Which Centre may be found Geometrically, as is formerly taught, or thus: Draw the right Line Z S, which divide in two equal parts in O, and upon O erect the Perpendicular O G, extending it, till that and the *Horizontal* Line do intersect; for the point of intersection shall be the Centre of the Meridian. Then lay a Ruler from Z to *c*, and it will cut the *Horizon* in W, the West point thereof.

An

An Upright Plain Declining from the South Westward 24 deg. 20 min.



Thirdly, Having drawn the *Meridian* and the *Horizon*, take 51 deg. 32 min. out of your Line of Chords, and ſet them upon your Plain, from H to B, and from N to *d*.

Fourthly, Lay a Ruler upon W, the Weſt point of the *Horizon*, (which is alſo the Pole of the *Meridian*) to *b*, and it will cut the *Meridian* in the point P, ſo ſhall P be the Pole of the World, through which point P, and Q (the Pole of the Plain) draw the ſtraight Line B P Q D, repreſenting the *Axis* of the World, and the Subſtilar Line of the Dial.

Fifthly, Lay a Ruler from W to *d*, and it will croſs the *Meridian* in the point Æ, ſo is Æ one point in the *Meridian*, through which the Equinoctial muſt paſs: And the point W in the *Horizon* is another. So have you two points within the Circle, by which to draw the Æquinoctial which you may do Geometrically, as is before taught. Or you may find it thus, the Centre of the Æquinoctial will always be in the *Axis* of the World, and therefore in the Line B P Q D. Now to find the point, draw the Line Æ W, which divide in two equal parts in the point *n*, upon *n* erect a perpendicular, till it cut the *Axis* of the World, extended in *m*. So is *m* the Centre of the Æquinoctial, upon which point you may deſcribe it. And thus have you drawn upon your Plain all the three Circles required, *viz.* the *Horizon*, *Meridian*, and the *Æquinoctial*; by which may be found the three Requiſites belonging to this Plain. For,

1. *To find the height of the Pole above the Plain, repreſented in the Scheme by the the Line* P B. Lay a Ruler to G, where the *Æquinoctial* cuts the Plain, and to P the Pole of the World, the Ruler will cut the Plain on the oppoſite ſide in the point *v*. So the diſtance from B to *v*, meaſured upon the Line of Chords, will be found to contain 34 deg. 33 min. The height of the Pole above the Plain.
2. *To find the diſtance of the Subſtile from the Meridian, repre-*

repreſented in the Scheme by the Arches Z B, *or* N D. Take in your Compaſſes the diſtance Z B, or N D, and you ſhall find either of them equal to 18 deg. 8 min. and ſuch is the diſtance of the Subſtile from the Meridian.

3. *To find the Plains difference of Longitude, repreſented in the Scheme by the Angle* Æ P K. Lay a Ruler from P to Æ, it will cut the Plain in *x*, ſo the diſtance between D and *x*, meaſured upon the Line of Chords, will be 30 deg. And ſuch is the Plains difference of Longitude.

Laſtly, Theſe Requiſites being obtained, we come to the drawing of the Hours; to effect which, lay a Ruler to P, the Pole of the World, and Æ, the Interſection of the *Æquinoctial* with the *Meridian*, and it will cut the Plain in the point *x*,——At this point *x* begin to divide the Semicircle L *x* G, into 12 equal parts, at the point ⊙ ⊙ ⊙, &c. Then laying a Ruler to Q, and every of theſe points ⊙ ⊙ ⊙ &c. it will cut the *Æquinoctial Circle*, dividing that into 12 unequal parts in the points ****, &c.—— Again, a Ruler laid to P, and every of theſe unequal parts ****, *&c.* will divide the Plain into 12 unequal parts in the points]]] *&c.* ----- Lay a Ruler to Q, and every of theſe points]]], *&c.* drawing lines by the ſide thereof, and they ſhall be the true Hour-lines proper to ſuch a Declining Plain.

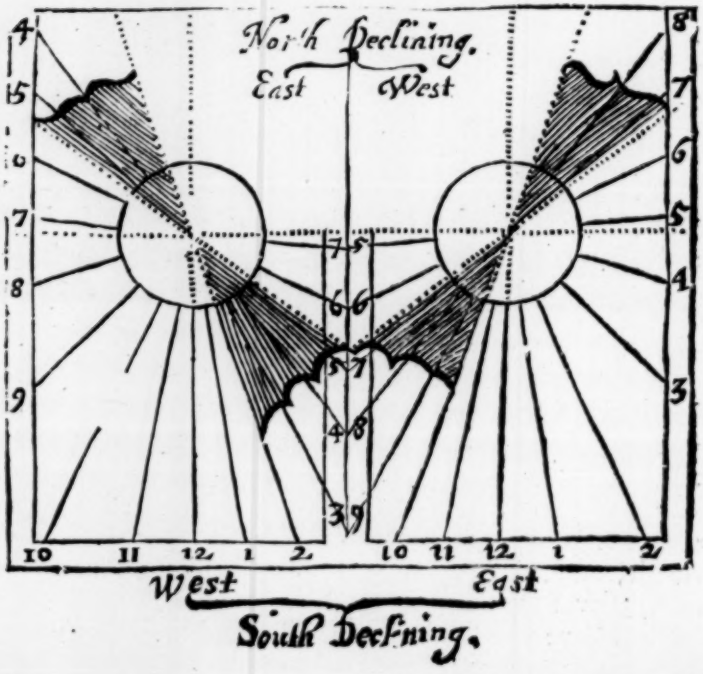
Thus have you finiſhed the Hour-lines, the Subſtilar-line, (or the line upon which the Stile muſt ſtand) is the line Q D, falling (in this Dial) juſt upon the Hour-line of 2 in the Afternoon, becauſe the Plain declined Weſtward. The Angle of the Stile is D Q R, containing 34 deg. 33 m. and muſt be either of Plate or Wire brought to ſuch an Angle, and muſt ſtand perpendicular to the Plain, and directly over the Subſtilar Q D.

Now have you finiſhed your Dial, and in ſo doing you have in this one made four Dials, *viz.*

		d.	m.
A	South declining Weſt South declining Eaſt North declining Weſt North declining Eaſt	24	20

Only placing of the numbers of the hours and the Stile reſpectively upon each Plain. For in the South Weſt Plain, which we have now deſcribed, the Stile ſtands upon the hour of 2 in the Afternoon; in the South Eaſt declining as much, it will ſtand upon the Hour-line of 10 before-noon. And ſo all the morning hours of the Weſt-decliner will be the Afternoon hours of the Eaſt decliner; and the Afternoon hours of the Weſt decliner, will be Morning Hours

The Four Upright Declining Dials.



of

of the Eaſt decliner: And ſo the South decliner will produce the North Weſt decliner; and the South Weſt decliner, the North Eaſt decliner, by only extending the Hour-lines, Stile and Subſtile quite through the Centre. And that there my yet remain no doubt, I have drawn all the four Dials in one, by which you may plainly ſee that there is no difference between them, but what hath been already intimated.

By this Figure you may plainly ſee, how that one Dial is the Product of all theſe four, by obſerving the cautions before delivered. So that it may ſeem ſuperfluous to ſay any more concerning theſe upright declining Dials. Only before I leave them, I will (becauſe theſe Dials are moſt in uſe) give you one other Example of an upright declining Plain, which by reaſon of its great declination from the Prime Vertical, or its Poles great deviation from the Meridian, cauſeth the Pole to have but ſmall Elevation, wherefore the Dial (as all ſuch like) muſt be drawn without a Centre, by the directions following.

CHAP. VIII.

How to draw the Hour-lines *upon Upright far* Declining Plains, *which by reaſon of the ſmall Elevation, which the* Pole hath *over ſuch Plains, the Hours (if they be drawn from a Centre) cannot be of any competent diſtance one from another.*

THoſe Plains which lie near to the Meridian Circle, and whoſe Poles (conſequently) near the prime Vertical Circle, or Azimuth of Eaſt or Weſt; the Pole hath but ſmall Elevation above ſuch Plains, ſo that the Hour-lines (eſpecially thoſe of them which fall near to the Subſtile) from the Centre, cannot be drawn at any competent diſtance, without a large extention of them. To remedy which inconvenience, you may draw the Hour-lines for ſuch a Plain at a convenient diſtance, and in a little room, without

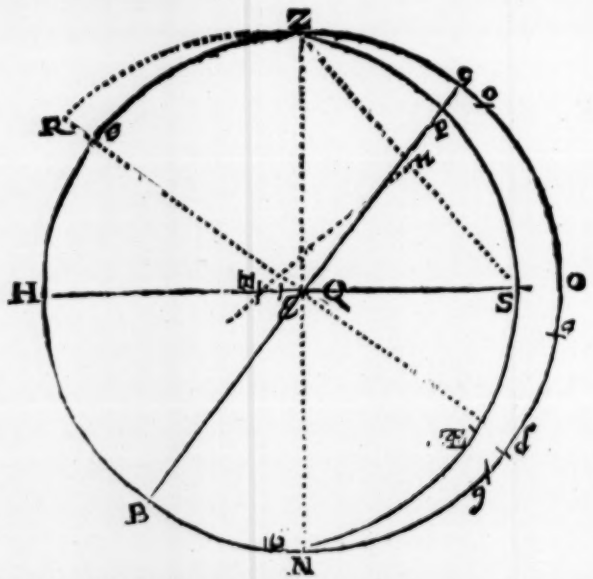
without any regard had to the Centre. But before you proceed to draw the Dial, you muſt firſt find the three requiſites mentioned in the laſt Chapter, *viz.*

1. *The* height of the Pole *above the Plain.*
2. *The diſtance of the* Subſtile *from the* Meridian.
3. *The Plains* difference of Longitude.

Example of an Upright South Plain, *declining Eaſtward* 80 *deg. in the Latitude of* London 51 *deg.* 32 *min.*

To find theſe Requiſites.

Firſt, Draw the Circle Z H N O, croſſing it with the diameters Z N, the perpendicular, and H O, the Horizontal Line of the Plain.



Secondly, Becauſe the Plain declineth 80 deg. Eaſtward, ſet 80 deg. from N to *a*, and from H to *b*.

Thirdly,

Thirdly, Lay a Ruler to Z and *a*, it will cut the *Horizon* in S, the South point thereof, and a Ruler laid to Z and *b*, will cut the *Horizon* in E, the Eaſt point thereof.

Fourthly, Having the three points Z S and N, through them draw the Meridian Z S N, whoſe Centre (by any of the ways before taught) will be found to be at *m*.

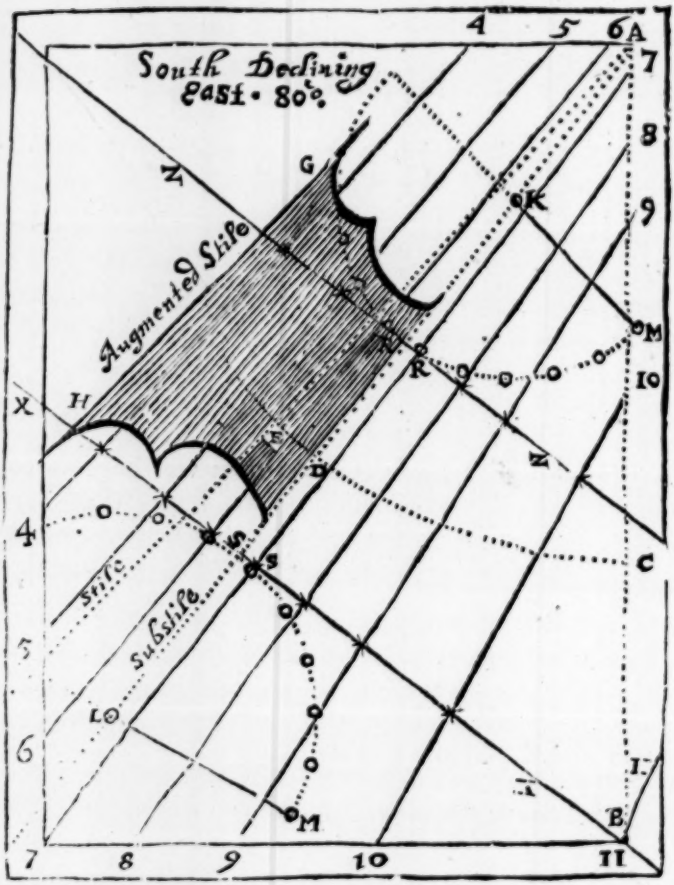
Fifthly, Out of your Line of Chords take 51 deg. 32 m. the Latitude, and ſet them from O to *c*, and from N to *d*. Then laying a Ruler from E to *c*, it will cut the *Meridian* in P the Pole of the World; through which point P and Q, the Centre of the Plain, draw the right line P Q B, for the Axis of the World. Alſo, the Ruler laid from E to *d*, will cut the *Meridian* in Æ, ſo is Æ one point in the *Meridian*, through which the Æquinoctial muſt paſs, and R is another point in the *Meridian* (extended) without the Circle, and a third point is E, the Eaſt point of the Horizon. Now foraſmuch as theſe three points R E Æ, through which the *Æquinoctial* is to be drawn, are almoſt in a ſtrait line, ſo that the Centre of it will be at a very great diſtance, we will forbear deſcribing of that Circle, and content our ſelves that we have found the points R E Æ, through which it ſhould paſs; becauſe we ſhall draw the Hour-lines in this and the like caſes by other means, and therefore I ſhall proceed to find the other Requiſites. And,

1. *To find the height of the Pole above the Plain repreſented by P C.* —— Take 90 deg. of your Line of Chords, and ſet them from *c* to *e*, a Ruler laid to *e* and P, will cut the plain in *o*, ſo is O C the height of the Pole (or Stile) above the plain, *viz.* 6 deg. 12 min.

2. *To find the diſtance of the Subſtile from the Meridian, repreſented by B N or Z C.* —— Take the diſtance B N or Z C (which is equal thereto) in your Compaſſes, and meaſure it upon your Line of Chords, ſo you ſhall find it to contain 38 deg. 4 min. which is diſtance of the Subſtile from the *Meridian*.

3. *To*

An Erect South Plain Declining Eaſtward 80 *deg.*



3. *To find the Plains difference of Longitude, repreſented by the Angle* ☌ *P Æ,* —— Lay a Ruler upon P and Æ, it will cut the Plain in *g*, the diſtance *g* B, meaſured

meaſured upon the Line of Chords, will contain 82 d. 8 min. the *Plains difference of Longitude.*

Theſe three Requiſites being thus found, I will now proceed to draw the Dial without any regard had to the Centre.

How to draw the Hour-lines upon the Plain.

Firſt, Draw a right line A B, for the perpendicular line of your Plain, and upon A as a Centre, with 60 deg. or the Radius of your Chord, deſcribe an obſcure Arch of a Circle C D E, and thereon from C to D, ſet 38 deg. 4 m. *the Subſtiles diſtance from the Meridian* before found, and draw the Line A D for the Subſtile, quite through the Plain.

Secondly, Take 6 deg. 12 min. *the height of the Pole above the Plain* from your Chord, and ſet them upon the ſame Arch from D to E, and draw the line A E for the *Stile.*

Thirdly, Foraſmuch as the Stile A E in this caſe is but of ſmall Elevation, *viz.* but 6 deg. 12 min. Draw the line G H parallel to A E, at ſuch convenient diſtance, as you ſhall think fit, for your new (or augmented) *Stile*, to ſtand from your Subſtile A D.

Fourthly, Aſſume any two points in the Subſtile A D, as R and S, and through theſe two points draw two infinite right Lines, both of them at right Angles to the Subſtilar line A D, as the lines Z Z, and X X.

Fifthly, From the point R, take with your Compaſſes the leaſt diſtance to the new augmented Stile G H, and ſet that diſtance upon the Subſtilar line, from R to K: Alſo, from the point S, take the leaſt diſtance to the new Stile G H, and ſet that diſtance alſo upon the Subſtilar line from S to L.

Sixthly, Upon the two points K and L (as upon two Centres) with 60 deg. or the Radius of the Line of Chords, deſcribe two portions of Circles, and in either of them ſet

off 82 deg. 8 min. *the Plains difference of Longitude*, as from *S* to M, and from R to M, both on the ſame ſide of the Subſtilar line, on which the perpendicular line of the Plain A B was drawn.

Seventhly, Divide either of the Semicircles laſt drawn, into 12 equal parts, at the points ⊙ ⊙ ⊙, *&c.* beginning this diviſion in either of them, at the point M.

Eightly, Lay a Ruler to the point L, and every of the diviſions ⊙ ⊙ ⊙, *&c.* and the Ruler will cut the Contingent or *Æquinoctial* line X X, in the points * * *, *&c.* Alſo a Ruler laid to K, and each of the points ⊙ ⊙ ⊙, *&c.* will cut the other Contingent Z Z, in the points * * *, *&c.*

Laſtly, Lines drawn from the point * in one Contingent line, to the point * in the other Contingent line, each to his correſpondent (which the Subſtilar line will direct you how to do) thoſe lines ſhall be the true Hour-lines belonging to ſuch a declining Plain, and be drawn as in the Figure you ſee done, at a competent diſtance one from another, without any relation at all had to the Centre of the Dial.

Thus have you finiſhed your Dial, and in the making of this, you have made a South declining Weſt 80 deg. alſo; for if you turn the Paper, and look through it, it will on the back-ſide be a South declining Weſt 80 deg. only the Forenoon hours in this, muſt be the Afternoon hours in that: Nay, in rigour, you have in this one Dial made four, *viz.* a North declining either Eaſt or Weſt, if you well obſerve what was ſaid and done in the laſt Chapter.

And thus have I done with all *Upright*, or *Erect Plains*, either *Direct* or *Declining*. I ſhall now proceed to ſhew you how to inſcribe Hour-lines upon ſuch Plains as are not Upright, but *Recline* from the *Zenith*, and of them there are ſuch as are *Direct*, and ſuch as do *Decline*.

III. *Of Reclining Plains.*

CHAP. IX.

AS in Upright Plains there were two Varieties, *viz. Erect Direct*, and *Erect Declining*. So are there of *Reclining Plains* alſo. For ſuch *Reclining Plains* as do directly behold either the true Eaſt, Weſt, North or South points of the Heavens, that is, whoſe Poles lie, either in the *Meridian*, or *Prime Vertical Circle* of the place, are called *Direct Reclining Plains*.

Again, Thoſe *Reclining Plains*, which do not directly lie in or their Poles be not in the *Prime Vertical* or *Meridian Circles* of the place, but deviate therefrom, are called *Declining Reclining Plains*. Of both which ſorts I ſhall give you an account, and the manner of inſcribing Hour-lines upon them, for in theſe Plains there is far more variety, than there was in *Upright* or *Erect Plains*.

Of Direct Reclining Plains, &c.

I. *Of* Eaſt *and* Weſt *Recliners.*

CHAP. X.

How to draw the Hour-lines upon a Direct Eaſt *or* Weſt Reclining *or* Inclining *Plain.*

AS in Upright Declining Dials, *Two* things muſt be given, and *Three* things muſt be found, before the *Hour-lines* could be drawn. In theſe direct Reclining Plains *Two* things muſt alſo be given, and *Three* muſt be found, before the Dial can be made.

The Things that muſt be given are,

1. The Latitude of the Place.
2. The Reclination of the Plain.

The *Reclination* of a Plain (as hath been before declared) is the Arch of an *Azimuth* or *Vertical Circle*, intercepted between the *Zenith* of the place, and the *Reclining Plain.*

Example, Of an Eaſt *or* Weſt Plain, Reclining 35 *deg. in the Latitude of* London 51 *deg.* 32 *min.*

		d.	*m.*
Data	Latitude of the Place	51	32
	Reclination of the Plain	35	00

Quæſita
1. The height of the Pole above the Plain.
2. The diſtance of the Subſtile from the Meridian.
3. The Plains difference of Longitude.

Firſt, Draw the Circle N E S R, repreſenting the Reclining Plain, and croſs it with the two Diameters N Q S, the Horizontal Line of the Plain, and Hour-line of 12 a Clock, and E Q R for the Prime Vertical Circle.

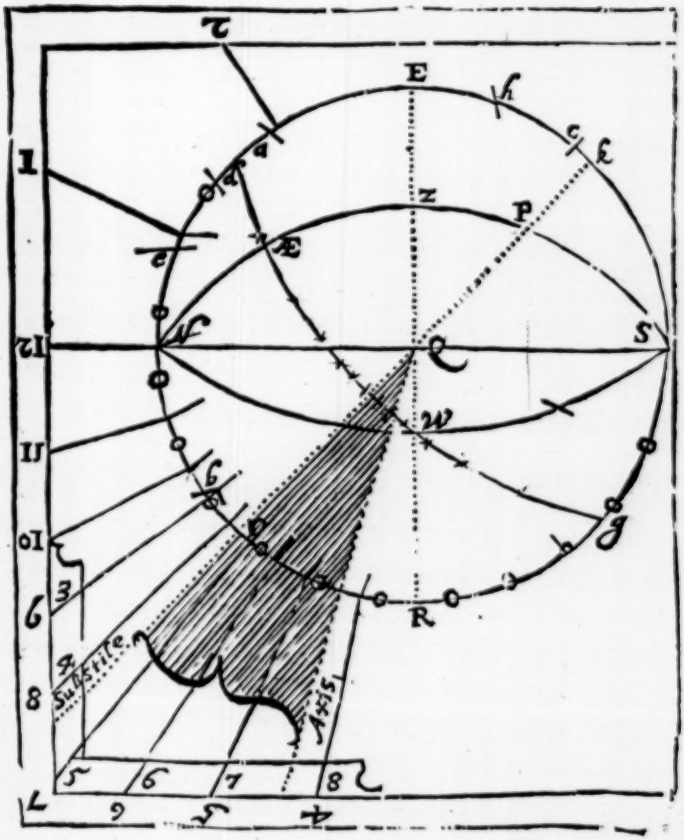
Secondly, Becauſe the Plain reclines 35 deg. take 35 deg. out of your Line of Chords, and ſet them from E to *a*, and from N to *b*.

Thirdly, Lay a Ruler from S to *a*, and it will cut the prime Vertical Circle in Z, ſo is Z the *Zenith* of the place---- Alſo a Ruler laid from S to *b*, will cut the ſame Vertical Circle in W, by which point the Horizon of the place muſt be drawn.

Fourthly, The points Z and W being found, you have three points through which you muſt deſcribe the *Meridian*, *viz.* N Z and S; and as many alſo through which you muſt draw the *Horizon*, namely, N W and *S*. The Centres of both which Circles will fall in the Line E Q R, (extended if need be) and the manner how to find them hath been often enough already taught.

Fifthly,

East and West Inclining.



Fifthly, Becauſe the Latitude of the place is 51 deg. 32 min. Take 51 deg. 32 min. from your Line of Chords, and ſet them upon your Plain from S to *c*. Then lay a Ruler upon W the Weſt point of the *Horizon*, and the point *c*, the Ruler will croſs the *Meridian* Circle in P the Pole of the World; through which point P and Q, the Centre

(or

(or pole of the Plain) draw the right line P Q, which ſhall be the *Axis of the World*, and Subſtilar Line of your Dial.

Sixthly, Take 90 deg. of your Line of Chords, and ſet them upon the Circle of your Plain from *c* to *d*, then lay a Ruler from W to *d*, and it will cut the *Meridian* Circle in Æ, ſo is Æ one point in the *Meridian*, through which the *Æquinoctial* Circle muſt be drawn, and W the Weſt point of the *Horizon* is another; ſo have you two points within the Circle, through which you muſt deſcribe the *Æquinoctial* Circle, whoſe Centre will be in the Line P Q, the Axis of the World, (extended if need be) the manner how to find it hath been already taught ſeveral ways.

Having thus projected the *Meridian*, *Horizon* and *Æquinoctial*, you may find the three Requiſites, as followeth.

1. *To find the height of the Pole above the Plain* P *k*, Lay a Ruler to *g* and P, it will cut the Plain on the oppoſite ſide in *h*; ſo *k h* meaſured upon the Chords, will be 26 deg. 41 min. *The height of the Pole above the Plain.*
2. *To find the diſtance of the Subſtile from the Meridian* S *k*, Take S *k* in your Compaſſes, and meaſure it upon the Chord, it will be found 45 deg. 52 min. *The diſtance of the Subſtile from the Meridian.*
3. *To find the Plains difference of Longitude*, Æ P Q, A Ruler laid from P to Æ, will cut the Plain in *e*, the diſtance from O the Subſtile, to *e*, will contain 66 deg. 27 min. of the Chord, which is *The Plains difference of Longitude.*

Theſe *Requiſites* being obtained, you may proceed to find the Hour diſtances upon the Plain in this manner.

Seventhly, Lay a Ruler to P the Pole, and Æ the interſection of the *Meridian* with the *Æquinoctial*, and it will cut the Plain in *e*. At *e* begin to divide the Semicircle into 12 equal parts, at the points ⊙ ⊙ ⊙ *&c.*

Eightly,

Eightly, Lay a Ruler to Q, and the ſeveral points ⊙ ⊙ ⊙ *&c.* and it will cut the *Æquinoctial* Circle in the points * * * *&c.* dividing that into 12 equal parts.

Ninthly, Lay a Ruler to P, and the ſeveral points * * * *&c.* and it will cut the Plain in the points | | | *&c.*

Laſtly, If from the Centre Q, you draw right Lines through the points | | | *&c.* they ſhall be the true Hour-lines belonging to your Reclining Plain.

And thus have you finiſhed your Dial, and alſo in it Four Dials: For the Dial as it here ſtands in the Scheme, is properly an Eaſt and Weſt Incliner, but being turned upſide down, as you ſee the hours numbred, and the word *Zenith* ſtanding upwards, it is an *Eaſt Recliner*; and if the Hour-lines be turned (or ſuppoſed to ſtand) on the right hand of the *Prime Vertical* Line E Q R, as in this Scheme they do on the left hand, and the hours of 4, 5, 6, *&c.* in the Morning, changed to 8, 7, 6, *&c.* in the Evening, the Plain is then a *Weſt Recliner*. And if the Hour-lines be drawn through the Centre of either of them, the Plains then become Eaſt and Weſt *Incliners*; the hours and Sub-ſtile in all retaining the ſame place, only the denominations of the Hours changed, *&c.* you muſt remember, that in all Eaſt and Weſt Recliners, the *North Pole* is elevated, and in all Incliners (oppoſite to them) the *South Pole*.

II. *Of South Recliners.*

CHAP. XI.

How to draw the Hour-lines *upon Direct* South Reclining *or* Inclining *Plains.*

IN the Eaſt and Weſt Reclining and Inclining Plains, before deſcribed, the *Meridian*, or 12 a Clock Hour-line, did lie in the *Horizontal* Line of the Plain, and the Poles thereof

thereof in the *Prime Vertical* Circle. So (on the contrary) in theſe South and North Reclining and Inclining Plains, their *Horizontal* line lieth in the *Prime Vertical* Circle, or hour of 6, and their Poles in the *Meridian*, and from hence they receive their denomination.

Of theſe Direct Reclining Plains there are *Six Varieties*, viz. three of South Recliners, and as many of North Recliners. For,

1. The South Plain may Recline, ſo as it may juſt fall in the Axis of the World, and ſo paſs through the Poles of the World, and then it is called an *Æquinoctial Plain*, becauſe the poles thereof lie in the *Æquinoctial* Circle, and neither of the poles have any Elevation above it, wherefore the Hour-lines muſt be all parallel one to the other, and all of them to the Axis of the World, and the Dial muſt be drawn as the Erect Direct Eaſt or Weſt Dials were. Only, whereas the Stile ſtood upon the Hour-line of 6 in the Eaſt and Weſt, in theſe plains it muſt ſtand up the Hour-line of 12, and be of equal height with the diſtance between the hours of 12 and 9, or 12 and 3, which are equidiſtant from the *Meridian*.

2. Or *Secondly*, The South Plain may ſo Recline, that it may fall between the *Zenith* and the North Pole, and then is the South Pole elevated above ſuch a Plain. Or,

3. The North Plain may ſo Recline, that it may fall between the Horizon and the North Pole, and then is the North Pole Elevated.

Examples of theſe three Varieties of South Reclining Plains do here follow.

The

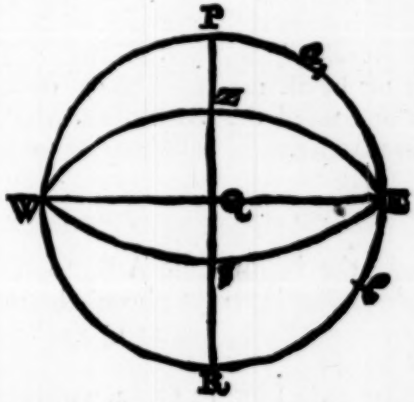
The Firſt Variety.

CHAP. XII.

How to draw the Hour-lines upon an Æquinoctial Plain, *Reclining juſt to the Pole.*

SUppoſe a South plain ſhould Recline 38 deg. 28 min: in the Latitude of *London* 51 deg. 32 min.

Firſt, Draw the Circle W P E R, repreſenting your Reclining plain, and croſs it with the two Diameters P Z S R, for the *Meridian*, and W Q E, the *Horizontal* line of the plain.



Secondly, Becauſe the plain Reclines 38 deg. 28 min. take 38 deg. 28 min. out of your Chord, and ſet them from P to *a*, and from E to *b*.

Thirdly, Lay a Ruler from W to *a*, it will cut the *Meridian* in Z, ſo is Z the *Zenith* of the place, through which point, and the points W and E (the Weſt and Eaſt points of the Horizon) draw the prime Vertical Circle W S E.

Fourthly, Lay a Ruler from W to *b*, and it will cut the *Meridian* in S, through the points W S and E, draw the Horizon of the place W S E.

Fifthly, Becauſe the Latitude of the place is 51 deg. 32 min. ſet 51 deg. 32 min. upon your plain from E to *a*, and it will cut the *Meridian* P Q R, in the point Z the *Zenith*, then (becauſe the pole of the World is removed from the *Zenith*, (always) ſo much as is the Complement of the Latitude, which here in this Example is 38 deg. 28 min.) take therefore this diſtance 38 deg. 28 min. and ſet it upon your plain from *a*, and you ſhall find, that the Compaſs-point will directly fall in the point P, which is the *Pole* of the World and is the very place where the Reclining *Plain*, and the *Meridian* of the place do interſect, which clearly demonſtrates, that the *Pole* hath no Elevation above this *Plain*, and by this means, the Line W Q E, becomes to be the *Æquinoctial*, and a ſtrait Line, wherefore the Hour-lines muſt be all parallel one to the other, and all of them to the Axis of the World, and the Dial muſt be drawn in this manner.

To draw the Hour-lines upon the Plain.

Firſt, Draw the Right Line A B, for the *Horizontal* Line of the *Plain*, and croſs it about the middle thereof at Right Angles, with the Line 12 Q 12 for the Meridian and Hour-line of 12.

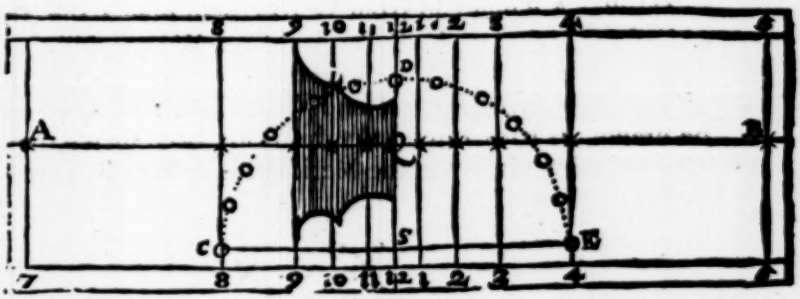
Secondly, Upon the Line 12 Q 12, either above or below Q, aſſume any point, as S, and ſetting one foot of your Compaſſes therein (it being opened to the Radius of your Line of Chords) deſcribe the Semicircle C D E, which divide into 12 equal parts, beginning at D.

Thirdly, Lay a Ruler to S, and the ſeveral points ⊙ ⊙ ⊙ *&c.* and it will croſs the *Æquinoctial* Line A B, in the points * * * *&c.*

Laſtly, Through theſe points * * * *&c.* draw Right Lines all

all parallel to the Line 12 Q 12, and ſo is your Dial finiſhed.

A Direct Æquinoctial Dial.



The Stile may be either a ſtrait Pin, of the length of the line Q S, ſet perpendicular to the Plain upon the point Q; the ſhadow of the top thereof only giving the Hour. Or it may be a plate of the breadth of the diſtance that is between the Hour-lines of 12 and 3, or 12 and 9. and then will the ſhadow of the upper edge thereof, give the hour of the day.

The Second Variety.

CHAP. XII.

How to draw the Hour-lines upon a Direct South Reclining Plain, *which falls between the* Zenith *and the* Pole.

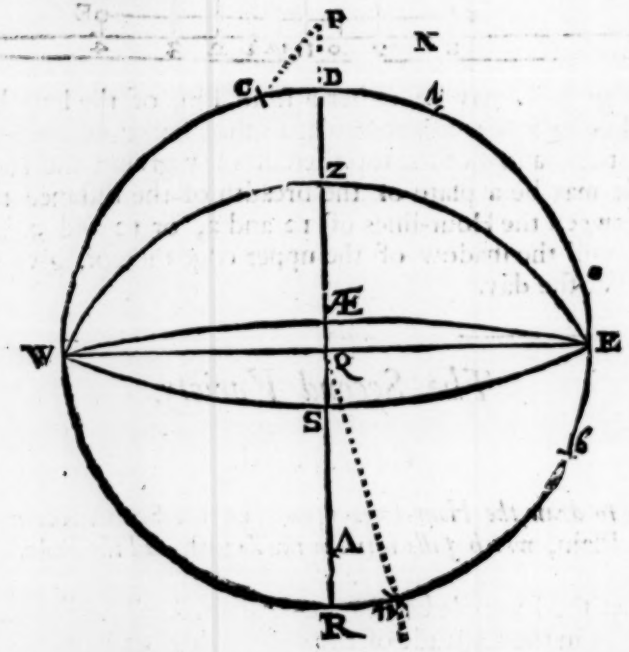
Let the Example be of a South Plain Reclining 25 d. in the Latitude of *London* 51 deg. 32 min.

Firſt, Draw the Circle W D E R, repreſenting your Reclining Plain, croſs it with the two Diameters N R,

for the *Meridian* and Hour-line of 12, and W E, for the *Horizontal* line of the Plain, and Hour-line of Six.

Secondly, Take 25 deg. the Plains Reclination, out of your Line of Chords, and ſet that Diſtance from D to *a*, and from E to *b*.

Thirdly, A Ruler laid from W to *a*, will give Z the *Zenith* of the place; and a Ruler laid from W to *b*, will give S the South point of the *Horizon*; both which Circles W Z E, the *Prime Vertical* and W R E the *Horizon*, may be drawn, as hath often enough already been ſhewn, their Centres being always in the Meridian Line N Q R, extended if need require.



Fourthly, Becauſe the Pole of the World is always diſtant from the *Zenith*, the Complement of the Latitude of the

the place, *viz.* here at *London*, 38 deg. 28 min. Take (therefore) 38 deg. 28 min. out of your Line of Chords, and ſet them upon your Plain from *a*, the point which found the *Zenith* to C.

Fifthly, Lay a Ruler from W to C, and it will cut the *Meridian* N Q R, (being thus extended) in *P*, ſo is *P* the North Pole of the World, and becauſe it falleth without Plain, it is evident by the Scheme, that this Reclining Plain paſſeth through the *Meridian*, between the *Zenith* and the Pole. And again, becauſe the North Pole *P* falleth without the Plain, it alſo demonſtrates that the South Pole muſt be elevated above this Plain. Wherefore,

Sixthly, To find the point of the South Pole upon the *Meridian* line N Q R, do thus. Becauſe the two Poles are 180 deg. diſtant from each other, *viz.* two Quadrants, or twice 90 deg. Take therefore 90 deg. out of your Line of Chords, and ſet them twice upon your Plain from C, *viz.* firſt from C to *e*, and then from *e* to *n*, ſo ſhall the 180 deg. end in *n*: And a Ruler being laid from W to *n*, ſhall croſs the *Meridian* in A, the South Pole; ſo is the South Pole A, elevated above the Reclining Plain, the quantity of A R, which is equal to the Arch R *n*, which meaſured upon the Line of Chords will be found 13 deg. 28 min.

Seventhly, Lay a Ruler from W to *e*, and it will cut the Meridian in Æ, ſo is Æ that point in the *Meridian* through which the *Æquinoctial* muſt paſs. As alſo through the points E and W, the Eaſt and Weſt points of the Horizon.

Eighthly, For the Hour-lines, They are to be drawn in all reſpects as the Hour-lines were upon the upright South Plain, without any alteration, only there the Stile was elevated according to the Complement of the Latitude 38 deg. 28 min. here it muſt be elevated only 13 deg. 28 min. as in the Scheme. The manner how the Hour-lines are to be put on, I ſhall only repeat, but I ſhall forbear drawing them, leaving that to your own practice, in regard there is no alteration at all from the Erect Direct South Plain.

Where-

Wherefore divide the Semicircle of your Plain W R E into 12 equal parts, (beginning at R, and ſo 6 equal parts on either ſide of the Meridian N Q R.) Then lay a Ruler to Q, and every of thoſe 12 diviſions, it will divide the Æquinoctial into 12 unequal parts. A Ruler laid from P to every of thoſe unequal parts in the Æquinoctial, will divide the Plain into 12 other unequal parts, through which laſt 12 unequal parts, and the Centre Q, if you draw right Lines, they ſhall be the true Hour-lines proper for the Plain.

And here by the way note, for that the Æquinoctial Circle in this Scheme is a very oblique Arch, the Centre of it will be very remote, and the Hour-ſpaces upon it (as alſo upon the Plain) will be very cloſe together in theſe ſmall draughts, which is occaſioned by the ſmall Elevation that the South Pole hath above this Plain, *viz.* but 13 deg. 28 min. which you might find without drawing of the Scheme by ſubſtracting 25 deg. the Plains Declination repreſented in the Scheme by the Line (or Circle) D Z, from Z P, the Complement of the Latitude of the place. And therefore, foreſeeing that the Pole hath but ſmall Elevation above the Plain, and alſo what Pole, whether North or South that is elevated: The better way will be to augment the Stile, and to draw the Dial according to theſe following Directions.

How to draw the Hour-lines upon the Plain.

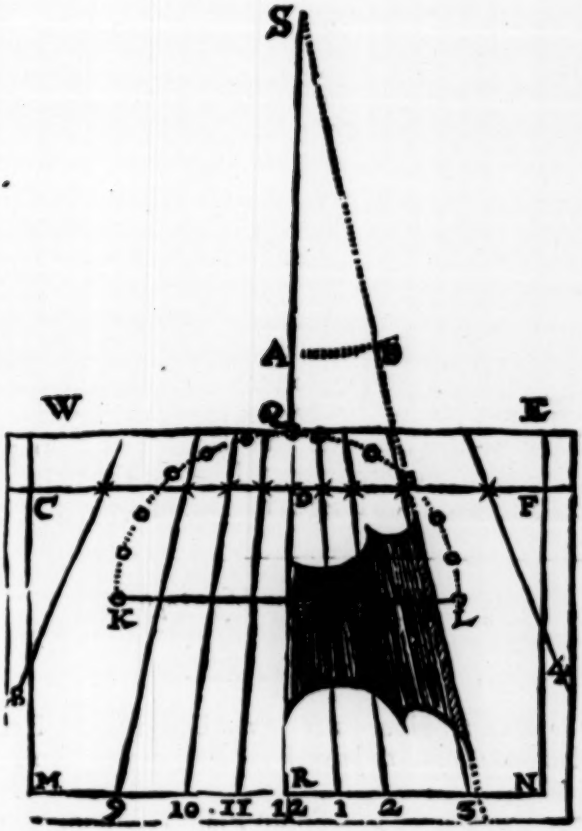
In the Scheme following, draw, *Firſt*, The right Line W Q E, for the *Horizontal*, and perpendicular thereunto, in the Line S Q R, for the *Meridian* and Hour-line of 12, which extend above the *Horizontal* Line to S.

Secondly, Upon S as a Centre, with 60 deg. of your Chord, deſcribe a ſmall Arch of a Circle, and upon it ſet

13 deg.

13 deg. 28 min. the height of the Pole above the Plain from A to B, and draw the Line S B for the Stile.

South Reclining 25 *Degrees.*



Thirdly, At any convenient diſtance, anſwerable to the largeneſs of your Plain, draw a Line parallel to W E, as the Line C D F.

Fourthly,

Fourthly, Set one Foot of your Compaſſes in D, and with the other, take the neareſt diſtance to the Stile S B, which diſtance ſet upon the *Meridian* from D to H.

Fifthly, Upon the point H, (your Compaſſes opened to 60 deg. of your Line of Chords) deſcribe the Semicircle K Q L, which divide into 12 equal parts, in the points ⊙ ⊙ ⊙ *&c.*

Sixthly, Lay a Ruler unto H, and upon every of the points ⊙ ⊙ ⊙, *&c.* and it ſhall cut the *Æquinoctial* Line C D F, in the points * * * *&c.* through which the Hour-lines muſt paſs: Wherefore, if from the Centre S, and through the ſeveral points * * * *&c.* in the Line C D F, you draw ſtrait lines, bounding them between any two lines as W E, and M N, they ſhall be the true Hour-lines. Or,

Seventhly, If you draw another Tangent line, and deſcribe another Semicircle, and divide it, and the other line, as you did the former, ſo ſhall the lines drawn through the reſpective points * * * *&c.* in either of the *Æquinoctial* (or Tangent-lines) be the true Hour-lines belonging to your Plain, without any regard had to the Centre at all, as you before did in Upright far Decliners.

The Third Variety.

CHAP. XIV.

How to draw the Hour-lines *upon a* Direct South Reclining Plain, *which paſſeth between the* Pole *and the* Horizon.

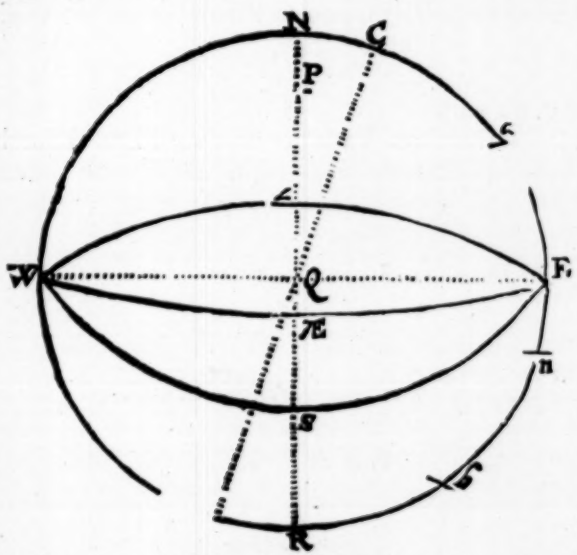
Let the Example be of a South Plain, Reclining 55 deg. in the Latitude of *London*, 51 deg. 32 min.

Firſt, Draw the Circle W N E R, for your Reclining Plain, croſs it with the two Diameters N Q R, the *Meridian*

Meridian, and W Q E, the *Horizontal* Line of the Plain.

Secondly, Take 55 deg. the Plains Reclination, out of your Line of Chords, and ſet that diſtance from N to *a*, and from E to *b*.

Thirdly, Lay a Ruler from W to *a*, it will cut the *Meridian* in Z, ſo is Z the *Zenith* of the place, through which, and the points W and E. draw the prime Vertical Circle W Z E.



Fourthly, Lay a Ruler from W to *b*, and it will cut the Meridian in S, the South point of the *Horizon*, through which, and the points W and E, the *Horizon* of the place W S E muſt be drawn.

Fifthly, The Pole being diſtant from the *Zenith* of the place 38 deg. 28 min. equal to the Complement of the Latitude, ſet 38 deg. 28 min. from *a* to *c*, and a Ruler laid from W to *c*, ſhall cut the *Meridian* in *P* the Pole of the World, and 90 deg. of your Line of Chords being ſet

from *c* to *n*, and a Ruler laid from W to *n*, ſhall cut the *Meridian* in Æ, through which, and the points W and E muſt the *Æquinoctial* Circle be deſcribed: The Centre whereof, as alſo of the *Horizon* and prime Vertical Circles, are all in the *Meridian* N Q R, extended where need requires, and how theſe Centres are to be found, is ſhewed already.

Sixthly, For the drawing of the Hour-lines, they muſt be drawn as in the Erect Direct South Plain, or as was directed in the laſt Plain, and ſo I ſhall ſay no more of them in this place; only take notice, that the North Pole is elevated above this Plain, the quantity of the Arch N *c*, which is 16 deg. 32 min.

Theſe are the three Varieties of South Direct Reclining Plains, and in the making of theſe, you have alſo made the oppoſite Incliners as much, for each Plain hath two faces, the one open to the *Zenith*, and the other to the Nadir of the place.

III. *Of North Direct Recliners.*

CHAP. XV.

How to draw the Hour-lines *upon a* Direct North Reclining Inclining *Plain.*

AS in *South Reclining Plains* there were Three Varieties, ſo alſo are there as many in the *North Recliners*; For,

1. The North Plain may ſo Recline, that it may paſs through the *Meridian*, juſt at the interſection of the *Meridian* with the *Æquinoctial*, the plain it ſelf lying in the Æquinoctial Circle, and the poles thereof in the Poles of the World, and ſo it is called *A Polar Plain.* Or,

2. The

2. The Plain may ſo Recline, that it may cut the Meridian between the *Zenith* and the *Æquinoctial.* Or,

3. It may Recline ſo far, as to cut the Meridian between the *Æquinoctial* and the *Horizon.*

Examples of theſe three Varieties of North Reclining Plains follow.

The Firſt Variety.

CHAP. XVI.

How to draw the Hour-lines upon a Direct Polar Plain, *which Reclineth juſt to the* Æquinoctial.

Example of a North Plain, Reclining 51 deg. 32 min. equal to the Latitude of the Place *viz.* London.

Firſt, Deſcribe the Circle E Æ W R, for your Plain, croſs it with the Diameters Æ Q R, for the Meridian, and W Q E for the prime Vertical Circle.

Secondly, Set 51 deg. 32 min. the Reclination of the Plain (which in this Example is alſo equal to the Latitude of the place) from Æ to *a*, and alſo from W to *b*.

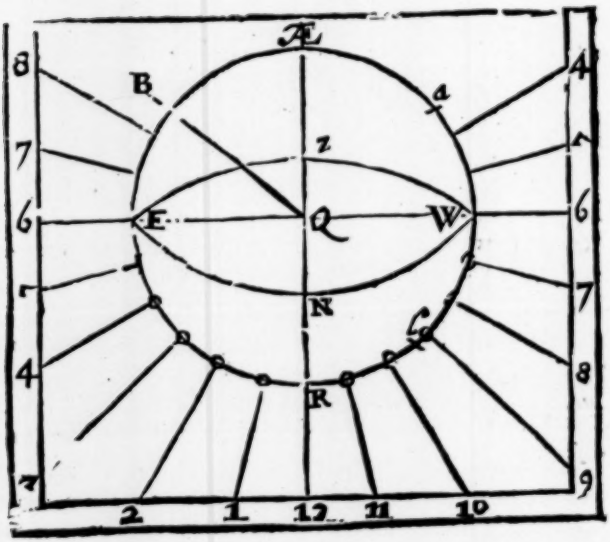
Thirdly, A Ruler laid from E to *a*, will cut the North part of the Meridian in Z the *Zenith* of the place, and being laid from E to *b*, it will cut the Meridian in N, ſo is N the North point of the Horizon.

Fourthly, Through the points W Z and E (by former directions) draw the prime Vertical Circle, or Azimuth of Eaſt or Weſt, W Z E. And alſo through W N and E, draw the Horizontal Circle W N E.

Fifthly, Becauſe the Pole of the World is always removed from the *Zenith* of the place, ſo much as is the Complement of the Latitude (in this Example 38 deg. 28 min.) Set 38 deg. 28 min. from *a* (the point in the Plain, which found the Zenith point Z,) Northward of the Zenith, and the Compaſs-point will fall in W, the Weſt point of the

Horizon; ſo that if a Ruler were laid from W to E, it would cut the Meridian in Q, for the Pole of the World, which is already the Centre of the plain, ſo that the pole of the World, and the pole of the plain fall both in one point, and the pole Q is elevated above the plain 90 deg. *viz.* the quantity of the *Meridian* Line Æ Q, or rather the Arch Æ W, which is the meaſure thereof.

A Direct Polar Dial South.



Sixthly, To draw the Hours upon this Plain, it is eaſieſt of all others, for if you divide the Semicircle E R W, into 12 equal parts in the points ⊙ ⊙ ⊙ *&c.* and through thoſe points draw ſtraight lines from the Centre Q, they ſhall be the true Hour-lines belonging to this *Polar Plain.*

And this Plain, by reaſon of its North Reclination, is, in Summer, capable of receiving all the hours from Sun riſing

to

to Sun ſetting, and therefore the Hour-lines of 4 and 5 in the morning, and of 7 and 8 at night muſt be drawn through the Centre, as you did in the Vertical or Horizontal Dial, and as you ſee here done in this Figure.

The Stile of this Dial muſt be a ſtrait Pin or Wire, ſet perpendicular upon the Plain, from the Centre Q, and of any length. And this for the Firſt Variety of North Recliners.

The South Inclining Plain oppoſite to this, is directly the ſame, only the forenoon hours in this muſt be the Afternoon hours in that, and the hours of 4 and 5 in the morning, and of 7 and 8 in the Evening muſt be omitted.

The Second Variety.

CHAP. XVII.

How to draw the Hour-lines upon a North Reclining *Plain, which interſects the Meridian between the* Zenith *and the* Æquinoctial.

Let the Example be of a North Plain, Reclining 25 deg.

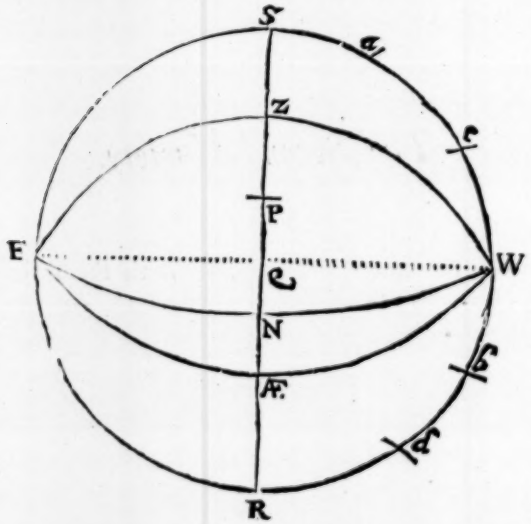
Firſt, Draw the Circle E S W R, repreſenting your North Reclining Plain, and croſs it with the two Diameters S Q R, the Meridian of the Place, and E Q W, the *Horizontal* Line of the Plain.

Secondly, Set the Reclination of the Plain 25 deg. from S to *a*, and from W to *b*.

Thirdly, Lay a Ruler from E to *a*, it will cut the Meridian in Z the *Zenith*. And a Ruler laid from E to *b*, will cut the Meridian in N the North point of the *Horizon*: ſo have you three points E Z and W, whereby to draw the prime Vertical Circle E Z W, and three points alſo, *viz.* E N and W, whereby to draw the *Horizon* E N W.

Fourthly,

Fourthly, Becauſe the Æquinoctial is always 90 deg. diſtant from either of the Poles, ſet 90 deg. upon your Plain, from *c* to *d*. Then laying a Ruler to E and *d*, it will cut the *Meridian* in Æ, ſo is Æ the point of the interſection of the Æquinoctial, with the North part of the *Meridian*; wherefore through the points E Æ W, deſcribe the Æquinoctial Circle; the Centre whereof, as alſo of the Horizon, and prime Vertical Circle, will fall in the Meridian S Q R, extended where need requires.



Fifthly, The Horizon, Æquinoctial and Pole, being thus ſeated in their true poſitions upon the Plain; the thing required in this Dial, is, *The height of the Pole above the Plain*, which may be found in this manner. ----- Lay a Ruler from E to P, and it will cut the Plain in *c*, the diſtance S *c*, meaſured upon your Line of Chords, will contain 63 deg. 28 min. which is the height of the pole above the Reclining Plain.

Laſtly, For the drawing of the Hours, that is done the ſame

ſame way as in the Erect Direct South Plain, only here the Stile muſt be elevated above the *Meridian* line 63 deg. 28 m. whereas there it was only 38 deg. 28 min. the Complement of the Latitude. The North Pole is elevated above this Plain, and the Hours that the Plain is capable to receive, are 4, 5, 6, 7, 8, and 9 in the Morning, and 3, 4, 5, 6, 7, and 8 at Night.

The height of the Pole (or Stile) above this Plain may be found by adding the Complement of the Latitude 38 deg. 28 min. and 25 deg. the Reclination together, the ſumm whereof is 63 deg. 28 min. the height of the Stile, as before.

The Third Variety.

CHAP. XVIII.

How to draw the Hour-lines upon a Direct North Reclining Plain, *which interſects the* Meridian *between the* Æquinoctial *and the* Horizon.

Let the Example be of a Direct North Plain, Reclining 70 deg. in the Latitude of *London* 51 deg. 32 min.

Firſt, Draw the Circle E S W R, repreſenting your North Reclining Plain, and croſs it with the two Diameters S Q R, for the *Meridian* of the Place, and with E Q W, the Horizontal Line of the Plain.

Secondly, Set the Reclination of the plain 70 deg. from S to *a*, and from W to *b*.

Thirdly, Lay a Ruler to E and *a*, it will cut the Meridian in Z the *Zenith*, through which, and the points E and W, draw the prime Vertical Circle E Z W. —— Alſo, lay a Ruler from E to *b*, it will cut the *Meridian* in N, the interſection

terſection of the *Meridian* with the North part of the Horizon, now through the points E N and W, deſcribe the Horizon of the place E N W.

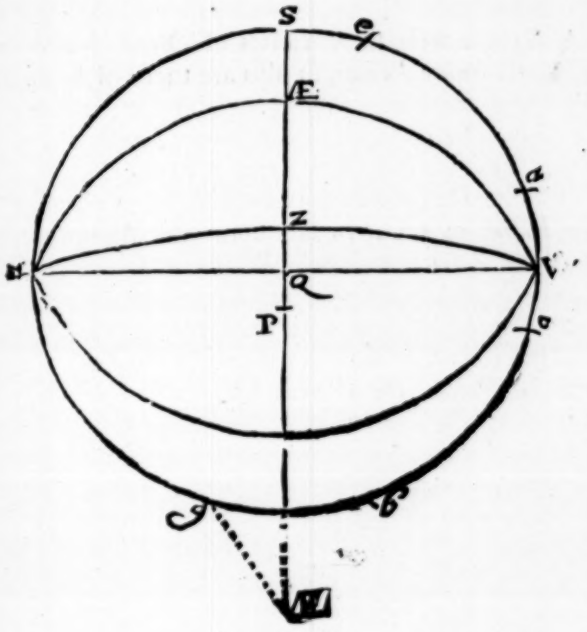
Fourthly, Foraſmuch as the Pole is diſtant from the *Zenith* of the place 38 deg. 28 min. (equal to the Complement of the Latitude) ſet 38 deg. 28 min. from *a*, the point which gave the Pole *P* to *c*, and lay a Ruler from E to *c*, ſo ſhall it croſs the Meridian in *P*, the Pole of the World.

Fifthly, Becauſe the Æquinoctial is in all places ſituate 90 deg. from either Pole. Take 90 deg. in your Compaſſes, and ſet them off from *c*, (the point which gave the Pole *P*) both ways, to *e* above, and to *g* below. So a Ruler laid from E to *g*, will cut the *Meridian* (it being extended) in Æ, without the Plain, which ſhews that the North part of the Æquinoctial Circle lies below this Plain. Therefore, lay a Ruler from E to *e*, and it will croſs the *Meridian* in Æ above, within the plain. So is Æ the point where the Meridian, and the South point of the Æquinoctial will interſect, and through that point, and the points E and W, muſt the Æquinoctial E Æ W, be drawn.

Sixthly, the Horizon, Pole and Æquinoctial, being thus projected, the thing required in this plain, is, *The height of the Pole above it, viz.* P R, which may be found in this manner. —— Lay a Ruler from E to *P*, and it will cut the plain in *c*, the diſtance from R to *c* meaſured upon the Chord, will be 71 deg. 32 min. which is the height of the pole above this Reclining plain. —— Or the height of the pole above the plain may be found, by adding the plains Reclination 70 deg. to 38 deg. 28 min. the Complement of the Latitude, the Summ whereof is 108 deg. 28 min. which taken from 180 deg. the remainer will be 71 deg. 32 min. as before.

Laſtly, For the drawing of the Hour-lines, they are done in all reſpects as thoſe before in South Erect Plains, only in this make the Elevation of the Stile 71 deg. 32 min. as you find it by your projection. Your

Your Hour-lines being drawn, erect the Stile 71 deg. 32 min. above the Meridian or Subſtile, letting it point up to the North Pole, becauſe that pole above this plain is ſo much elevated, and being this Plain is but 20 deg. raiſed above the Horizon, *viz.* the Complement of its Reclination, the Plain is capable to receive all the hours from 4 in the morning, to 8 at night, and therefore the hours of 4 and 5 in the morning, and 7 and 8 in the evening, muſt be drawn through the Centre, as was done in the *Vertical* or *Horizontal Dial.*



And thus have you had Examples of all the Varieties, both of *Eaſt*, *Weſt*, *North*, and *South Reclining Plains*; and no other can poſſibly fall out in any place whatſoever.

ſoever. The *Inclining Plains* are the ſame with the *Recliners* oppoſite to them; and muſt be drawn in the ſame manner, as hath been (in ſome meaſure) heretofore hinted, and ſhall be more at large diſcourſed of hereafter, when I have done with *Declining Reclining Plains*, of which I come now to treat.

IV. *Of Declining Reclining Plains.*

CHAP. XIX.

AS there were ſix Varieties of *Direct North and South Reclining Plains*, ſo alſo are there of *South* and *North Declining Reclining Plains*, *viz.* Three Varieties of *South Recliners Declining*, and as many of *North Recliners Declining*. For, in *South Recliners Declining*,

1. The *Declination* may be ſuch, that the *South Reclining Plain*, may cut or fall upon the *Meridian*, juſt upon the *Pole Point*; and ſuch *Reclining Declining Plains*, are called *Æquinoctial Decliners*: Or,

2. The *Declination* may be ſuch, that the *Reclining Plain* ſhall interſect the *Meridian* between the *Zenith* of the place, and the *Pole of the World*: Or,

3. The *Declination* may be ſuch, that the *Reclining Plain* ſhall croſs the *Meridian* between the *Pole* and the *Horizon*.

Theſe are the three Varieties of South Recliners Declining.

In North Recliners Declining *there are three other Varieties. For*,

1. The *Declination* may be ſuch, that the *North Reclining Plain* may croſs the *Meridian* in the point where the *Æquinoctial* interſects the *Meridian*. And then ſuch Plains

are

are called *Polar Declining Plains*, becauſe the Poles of them lie in the *Axis* of the *World*, and the *Subſtile* in ſuch Plains, will be always perpendicular to the *Meridian* of the place. Or,

2. The *Declination* may be ſuch, that the *Reclining Plain* may interſect the *Meridian*, between the *Zenith* and the *Æquinoctial*. Or,

3. The *Declination* may cauſe, that the *Reclining Plain* may fall upon the *Meridian*, between the *Æquinoctial* and the *Horizon*.

Examples of all theſe Varieties follow.

I. *Of South Recliners.*

The Firſt Variety.

CHAP. XX.

How to draw the Hour-lines *upon a* South Reclining Declining Plain, *which cutteth the* Meridian *in the* Pole *Point.*

IN Declining Reclining Dials, before the Hour-lines can be drawn, Three things muſt be given, and Four things found; the things given are,

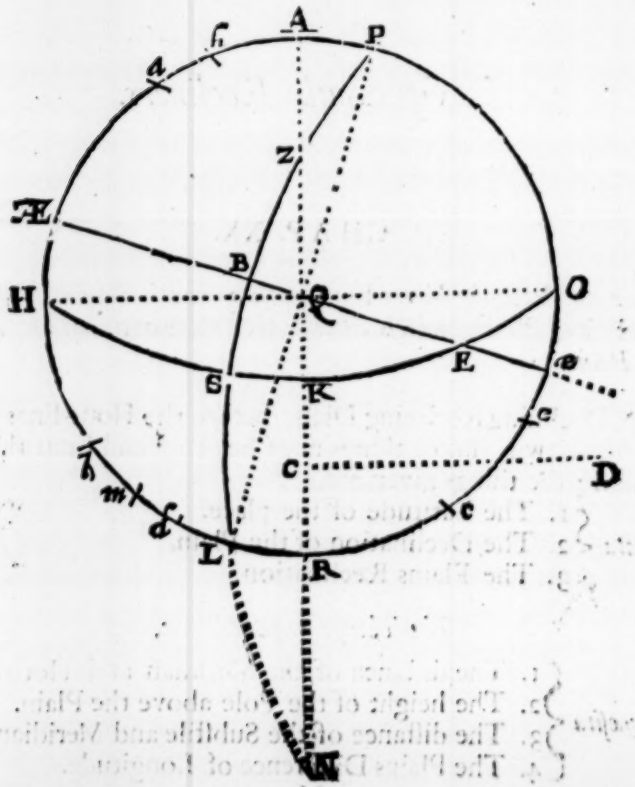
Data
1. The Latitude of the place.
2. The Declination of the Plain.
3. The Plains Reclination.

The Things required are,

Quæſita
1. The diſtance of the Meridian and Horizon.
2. The height of the Pole above the Plain.
3. The diſtance of the Subſtile and Meridian.
4. The Plains Difference of Longitude.

Let the Example *be of a* South Plain Declining East, 30 *d. and* Reclining 34 *deg.* 32 *min. in the Latitude of* London, 51 *deg.* 32 *min.*

First, Draw the Circle H A O R, and croſs it with the two Diameters H O, the Horizontal Line of the Plain, and A Q R, the perpendicular Line of the plain, croſſing each other at Right Angles in Q the Centre of the Plain.



Secondly,

Secondly, Becauſe the Plain Reclined 34 deg. 34. min. Take 34 deg. 34 min. from your Line of Chords, and ſet them upon your plain from A to *a*, from H to *b*, and from R to *c*.

Thirdly, Lay a Ruler from O to *a*, and it will cut the perpendicular Line of the Plain in Z the Zenith of the place. Alſo a Ruler laid from O to *b*, will cut the plains perpendicular in K, the interſection of the Horizon of the place, with the Plains perpendicular. And a Ruler laid from O to *c*, will cut the perpendicular of the plain A R (it being extended) in N the Nadir point. Having found theſe points upon the perpendicular Line of the Plain,

Fourthly, Through the points H K O, draw the Horizon of the place. And,

Fifthly, Becauſe the Plain declines 30 deg. Eaſtward, take 30 deg. out of your Chord, and ſet them from R to *d*, and from O to *e*; and laying a Ruler from Z the Zenith to *e*, it will croſs the Horizon in E, the Eaſt point thereof, and the Ruler laid from Z to *d*, will croſs the Horizon in S the South point thereof, ſo have you found three points, *viz.* Z N and S, through which you may draw the Meridian, whoſe Centre you may find, as hath been before taught: Or in this manner;

Divide the ſpace between Z and N in two equal parts in C, and through C draw the line C D parallel to Q O, extending it, as you ſhall have occaſion. Alſo from Q, through E draw another Right Line Q E, extending it, as occaſion ſhall offer; the point of thoſe two lines interſection, is the Centre of the Meridian. Which being drawn,

Sixthly, Lay a Ruler from E the Eaſt point of the Horizon to Z the Zenith, and it will cut the Plain in *h*. And, becauſe the Pole of the World is diſtant from the Zenith 38 deg. 28 min. equal to the Complement of the Latitude, ſet 38 deg. 28 min. from *h* upon the Plain, and it will fall juſt upon *P*, which is the point of the plains interſection with the Meridian, which demonſtrates the pole to have no elevation above the plain, and ſo the plain to be *Æquinoctial Declining*.

Seventhly,

Seventhly, Draw the Line P Q L for the Axis of the World, and, becauſe the Æquinoctial Circle is in all parts diſtant from either Pole 90 deg. ſet 90 deg. from P or L, to Æ; and through Q, draw the Line Æ Q æ, for the Æquinoctial Circle, which is here a ſtrait Line, and being extended, would paſs through the Centre of the Meridian, and alſo through the Eaſt and Weſt points of the Horizon, as it ought to do.

The Scheme being thus projected, the four Requiſites from it are eaſily obtained. For,

1. *To find the diſtance of the Meridian, and the Horizon* O P. The Arch O P meaſured upon your Line of Chords will contain 71 d. 53 min. the diſtance required.
2. *The height of the Pole above the Plain* (the point P) 00 *deg* 00 min. therefore it is an Æquinoctial Declining Plain.
3. *The diſtance of the Subſtile and the Meridian*, the point P alſo. Therefore that, as alſo all the hours, muſt be parallel to the Subſtile.
4. *To find the Plains difference of Longitude*, Q P B. Lay a Ruler from P to B, and it will cut the plain in *m*, the diſtance L *m* meaſured upon your Chord, is the plains difference of Longitude 24 deg. 19 min.

Theſe Requiſites being thus found, I will now ſhew.

How the Hour-lines are to be drawn upon the Plain.

Firſt, Draw a Line as B A C for the Horizontal Line of your plain, and upon any convenient point therein, as upon A, with 60 deg. or the Radius of your Line of Chords, deſcribe the Semicircle B D C.

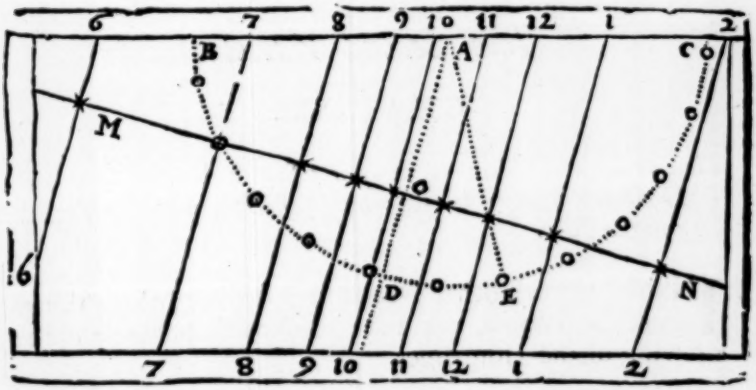
Secondly, From your Line of Chords take 71 deg. 53 m. the diſtance of the Meridian and Horizon, and ſet them from B to D, and draw the Line A D for the Subſtile.

Thirdly Take 24 deg. 19 min. the plains difference of Longitude, and ſet that diſtance from D to E, and draw the line A E.

Fourthly,

Fourthly, Divide the Semicircle B D C into 12 equal parts at the points ⊙ ⊙ ⊙ *&c.* beginning the diviſion at the point E.

A South Plain Declining East 30 *d. Reclining* 34 *d.* 32 *m.*



Fifthly, Through the point O, (or any other point taken at all adventures in the Subſtilar Line) draw a Line M O N at right Angles (or perpendicular) to the Subſtilar, repreſenting the Æquinoctial.

Sixthly, Lay a Ruler from A, and every of the points ⊙ ⊙ ⊙ *&c.* in the Semicircle, and it will croſs the Æquinoctial in the points * * * *&c.*

Laſtly, If through theſe points * * * *&c.* you draw right lines parallel to the Subſtilar, they ſhall be the true Hour-lines belonging to your plain, the hour-line of 12 being that where you began to divide your Semicircle, that is, at the mark (or *) which was made from the point E.

For the Stile of this Dial, it may be either a ſtrait pin or Wire, of the juſt length of the line A O, erected perpendicularly upon ſome point of the Subſtile (as at A or O) the very top of the ſhadow thereof giving the hour among the Hour-lines upon the Dial.

Or

Or elſe the Stile may be a Plate of Braſs or Iron of the breadth of A O, ſet perpendicular to the Plain, upon the Subſtilar Line A O D, the ſhadow of whoſe upper edge ſhall give the true hour of the day.

The Second Variety.

CHAP. XXI.

How to draw the Hour-lines *upon a* South Reclining Plain, *Declining* Eaſt *or* Weſt, *which paſſeth between the* Zenith *and the* Pole.

IN this, as in all other Decliners Reclining, three things muſt be known, and four muſt be found before the drawing of the Hour-lines.

Let the Example be a South Reclining Plain, Declining *Eaſt* 30 *deg. and* Reclining 20 *deg. in the Latitude of* 51 *deg.* 32 *min.* London.

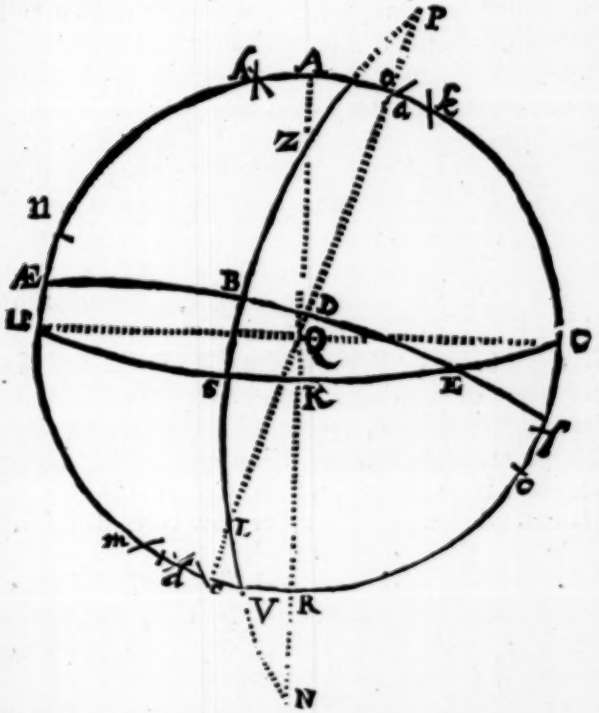
Data	1. Latitude of the place	51	32
	2. Declination South Eaſt	30	00
	3. Reclining South	20	00

Quæſita
1. The diſtance of the Meridian and Horizon.
2. The height of the Pole above the Plain.
3. The diſtance of the Subſtile and the Meridian.
4. The Plains difference of Longitude.

Firſt, Deſcribe the Circle H A O R, repreſenting your Reclining Declining Plain, and croſs it at right Angles, with the two Diameters A R, for the perpendicular, and H O for the Horizontal Line of the Plain.

Secondly,

Secondly, Take 20 deg. the plains Reclination, out of your Chord, and ſet them from A to *a*, from O to *b*, and from R to *c*.



Thirdly, A Ruler laid from H to *a*, will give you Z the Zenith, and laid from H to *b*, will give you K the interſection of the Horizon, with the perpendicular line of the Plain. And the Ruler laid from H to *c*, will give you N the Nadir, then through the points H, K and O, draw the Horizon H K O.

Fourthly, Take 30 deg. the Plains Declination out of your Line of Chords, and ſet them from R to *d* Weſtward, (becauſe the plain declines Eaſtward) and alſo from O to *e*, ſo a Ruler being laid from Z to *e*, ſhall cut the Horizon in E,

the East point thereof, and laid from Z to *d*, shall cut the Horizon in S the South point thereof. Thus have you three points Z, S and N, through which to draw the Meridian Circle, which you may extend without the plain to P and N, occasion sometimes requiring it should be so.

Fifthly, Forasmuch as the Pole of the World is always distant from the *Zenith*, equal to the Complement of the Latitude of the place, as here at *London* 38 deg. 28 min. Lay a Ruler from E to Z, and it will cut the plain in *h*, from whence set 38 deg. 28 min. to *k*. So a Ruler laid from E to *k*, will cut the *Meridian* (extended) in the point P, the North Pole of the World. And a Ruler laid from P to Q, shall cross the *Meridian* in L, the South Pole, and the Line P Q L shall be the Axis of the World.

Sixthly, Take 90 deg. of your Chords, and set them from *k* the point, which found the Pole at P to *n*: So a Ruler laid from E to *n*, shall cut the *Meridian* in B, through which point, and through the point E, the Æquinoctial Circle must be described, whose Centre will be in the Axis P L extended, and the manner how to find it, hath been several times already discovered.

The *Horizon*, *Meridian*, and *Æquinoctial* Circles being thus described upon your Plain, by their intersections, and distances, the four Requisites belonging to this Declining Reclining Plain may be obtained. As,

1. *To find the distance of the Meridian and Horizon* H V. The distance H V upon the Plain, measured upon the Line of Chords, will contain 78 deg. 50 min. the distance of the *Meridian* and *Horizon*.
2. *To find the height of the Pole or Stile above the Plain* L C. Set 90 deg. from *c* to *b*, then lay a Ruler from *b* to L, and it will cut the Plain at *m*, the distance from *c* to *m*, measured upon your Chords, will contain 13 d. 40 min. the height of the Pole or Stile above the Plain.
3. *To find the distance of the Substile from the Meridian*

V c, meaſure the diſtance *V c* upon the Line of Chords, and it will contain 7 deg. 30 min. the diſtance required.

4. *To find the Plains difference of Longitude*, *B L D.* Lay a Ruler from L to B, it will cut the Plain in *h*, ſo the diſtance *h* O meaſured upon the Line of Chords, will contain 28 deg. 52 min. the Plains difference of Longitude.

Thus are the four Requiſites belonging to this Plain found, and in this Example, two things are very obſervable.

1. Whereas P the North Pole of the World, falls without the plain, and the point L, repreſenting the South Pole falls within the plain, it denotes, that the South Pole muſt be elevated.

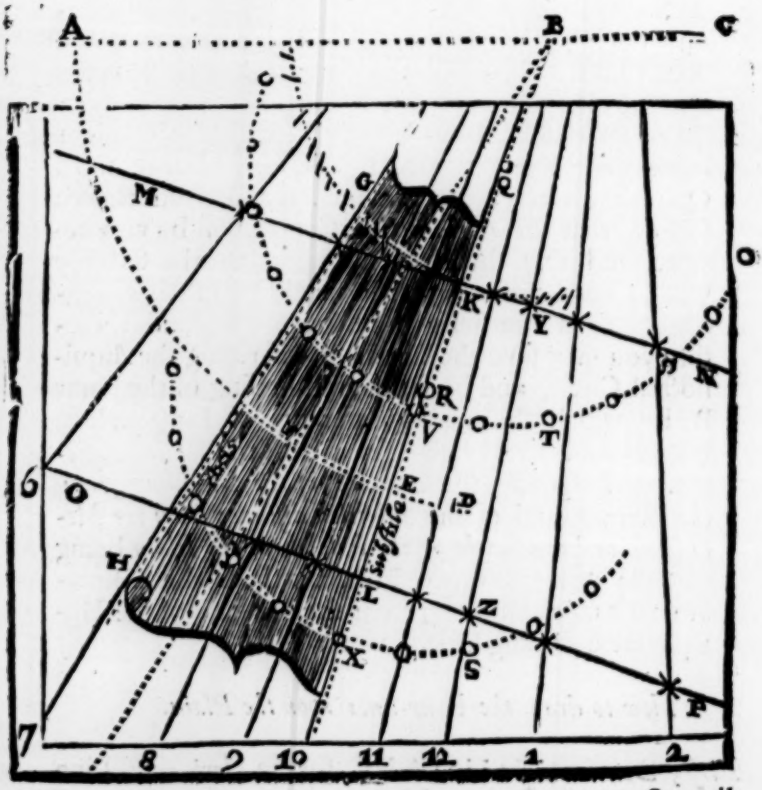
2. In reſpect that the Line or Arch L *c*, which is the height of the Stile or pole above the plain, is but of ſmall Quantity, *viz.* 13 deg. 40 min. it will from thence follow, that the *Æquinoctial's* Centre will be very remote, and that the Hour-lines near to the Subſtile will be very cloſe, ſo that in ſmall Dials their diſtances one from another will be inſenſible; and therefore you may ſave the labour of deſcribing the Æquinoctial Circle, and be ſatisfied in finding of the point B, by which the plains difference of Longitude is found——For, in ſuch caſes as this, the *Plains difference of Longitude*, the *diſtance of the Meridian from the Horizon*, and of the *Subſtiles diſtance from the Meridian*, and the *height of the Pole above the Plain* being gained; you may proceed to draw the Dial as followeth, not much differing from the drawing of the Upright far declining Dial Chapter VIII.

How to draw the Hour-lines upon the Plain.

Firſt, Draw a right Line A B C, for the *Horizontal* Line

of your Plain, and aſſume any convenient place therein, as B for a Centre; upon which point, with 60 deg. of any large Line of Chords, [*For it is neceſſary, not only in this, but for divers other occaſions, to have ſeveral Lines or Scales of Chords upon your Ruler*] deſcribe the Arch of the Circle A D. Upon this Arch, from A to D, ſet 78 deg. 50 min. the diſtance of the *Meridian* from the *Horizon*, and note the point D, but you need not draw the *Meridian* Line.

South Declining Eaſt 30 *deg. Reclining* 20 *deg.*



Secondly,

Secondly, From D to E ſet 7 deg. 30 min. the diſtance of the Subſtile from the *Meridian*, the ſame way as you find it to lie in your projection, and draw the Line B E for the Subſtile. Alſo, upon the ſame Arch, ſet off 13 deg 40 m. the height of the Stile from E to F, and draw the line B F for the Stile. Which being but of ſmall Elevation, *viz.* 13 deg. 40 min. ought to be augmented; and therefore (at any convenient diſtance (ſuitable to the bigneſs of your Dial-plain) draw a line as G H, parrallel to B F, for your augmented Stile or Axis.

Thirdly, Through any two points taken at adventure, in the Subſtilar line, as K and L, draw two righ lines perpendicular, or at right Angles to the Subſtilar, as the Lines M K N, and O L P. Then from the point K, take the leaſt diſtance to the augmented Stile G H, and ſet that diſtance upon the Subſtilar K to Q. Alſo from the point L, take the neareſt diſtance to the augmented Stile G H, and ſet that diſtance upon the Subſtilar from L to R.

Fourthly, Upon the points Q and R, as upon two Centres, with 60 deg. of any of your Chords, deſcribe two Semicircles (or other portions of Circles) and in either of them ſet 28 deg. 52 min. from V to T upon one of them, and from X to S upon the other.

Fifthly, Lay a Ruler from Q to T, and it will cut the Tangent Line in Y: Alſo lay a Ruler from R to S, it will cut the other Tangent line in Z, and a right line drawn through the points Y and Z, ſhall be the Hour-line of 12.

Sixthly, At the points S and T, begin to divide the ſeveral Semicircles in 12 equal parts or hours, by taking 15 d. of your Chord, and ſetting them from S and T both ways, at the points ⊙ ⊙ ⊙ *&c.* ſo many times as the plain will receive Hour-lines.

Seventhly, Lay a Ruler from the points Q and R, to every of the points ⊙ ⊙ ⊙ *&c.* in their reſpective Semicircles, and it will croſs their ſeveral Tangent lines in the points *** *&c.*

Laſtly,

Laſtly, Through the points * * *, in both the Tangent lines, draw right lines, each to his correſpondent, which the Hour-line of 12 will direct you how to do, and thoſe ſhall be the true Hour-lines of your Plain.

For the Stile of this Dial, it may be either of Wire, or Plate, containing an Angle equal to the height of the Pole above the Plain, but it muſt be augmented anſwerable to the augmented Stile, as you ſee in the Figure, and muſt be ſet in its proper place upon the Subſtilar line, and alſo perpendicular or ſquare to the Plain, and ſo is this Dial finiſhed.

The Third Variety.

CHAP. XXII.

How to draw the Hour-lines upon a South Reclining Plain, *Declining* Eaſt *or* Weſt, *which interſects the* Meridian *between the* Pole *and the* Horizon.

LEt the Example for this third and laſt Variety of South Declining Reclining Plains, be of a *South Plain Declining Eaſtward* 30 *deg.* and *Reclining* 55 *deg.* in the Latitude of 51 deg. 32 min. *viz.* London.

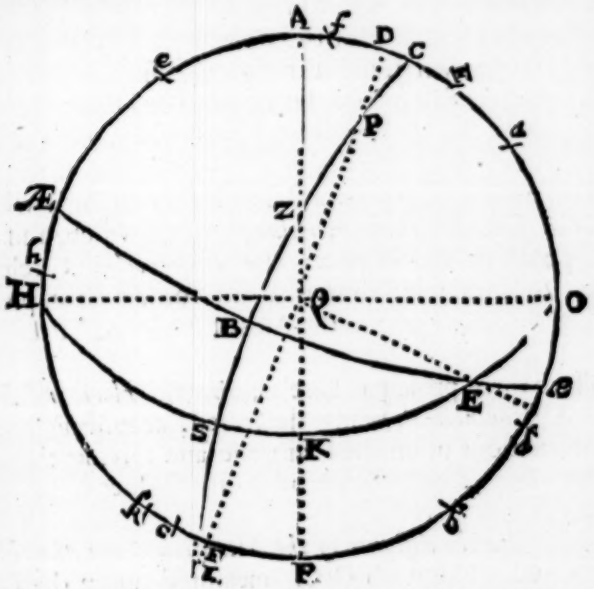
		deg.	min.
Data	The Latitude of the Place	51	32
	The Declination Eaſtward	30	00
	The Reclination	55	00

Quæſita
- The diſtance of the *Meridian* from the *Horizon.*
- The height of the Pole or Stile above the Plain.
- The *Subſtiles* diſtance from the *Meridian.*
- The Plains difference of Longitude.

Firſt,

First, Draw the Circle A H R O, for your Reclining Declining Plain, and croſs it with the two Diameters A R the Vertical, and H O the *Horizontal* line of the Plain.

Secondly, ſet 55 deg. the Plains Reclination from A to *a*, and from O to *b*.



Thirdly, Lay a Ruler from H to *a*, and it will give you Z the *Zenith*, and laid from H to *b*, it will give you K, the point of the *Horizons* interſection with the Plains Vertical Line. So have you three points H K and O, through which to deſcribe the Horizon of the place H K O.

Fourthly, Set 30 deg. the Plains Declination from R to *c* Weſtward, (becauſe the Plain declines Eaſtward) and from O to *d*. So a Ruler laid from Z to *c*, ſhall give you S, the interſection of the *Meridian* with the South point of the *Horizon*. And the Ruler laid from Z to *d*, ſhall give you E the Eaſt point of the *Horizon*.

Fifthly, Having the Points S and Z, through them you may

may draw the *Meridian* Circle L S Z P, as hath been already ſeveral ways taught, the Centre whereof will fall in the Line Q E being extended.

Sixthly, Lay a Ruler from E to Z, and it will cut the Plain in *e*, from which point *e*, ſet 38 deg. 28 min. to *f*, and a Ruler being laid from E to *f*, ſhall give the point P, upon the *Meridian* Circle, for the Pole of the World. And a Right Line drawn from P through Q, ſhall be the Axis of the World, and the Subſtilar line of the Dial.

Seventhly, Set 90 deg. from *f* to *h*, (becauſe the *Æquinoctial* Circle is in all places 90 deg. diſtant from either Pole, P or L.) So laying a Ruler from E to *h*, it will give you the point B in the *Meridan*, through which, and E, the Eaſt point of the *Horizon*, the *Æquinoctial* Circle muſt paſs. And may be drawn as in former Examples, the Centre thereof being in the Axis of the World, P L extended.

Theſe three principal Circles, *viz.* the *Horizon*, *Meridian* and *Æquinoctial*, being deſcribed, according to their true Situations upon the Plain, the ſame forementioned Requiſites may from thence be eaſily deduced, as followeth.

1. *To find the diſtance of the Meridian from the Horizon* O C. The Arch O C, meaſured upon the Line of Chords, will contain 64 deg. 41 min. *The Subſtiles diſtance from the Meridian.*
2. *To find the height of the Pole or Stile above the Plain* P D. Set 90 deg. from D to *æ*, and lay a Ruler from *æ* to P, it will cut the Plain in *m*, the Arch D *m* meaſured on the Line of Chords, will contain 19 deg. 25 min. *The height of the Stile.*
3. *To find the Subſtile's diſtance from the Meridian* C D. This Arch meaſured, will contain 6 deg. 2 min. *The diſtance of the Subſtile from the Meridian.*
4. *The Plains difference of Longitude* B P Q. A Ruler laid from P to B, will cut the Plain in *k*. So the diſtance

F *k*

F *k* meaſured, will be 17 deg. 38 min. *The Plains difference of Longitude.*

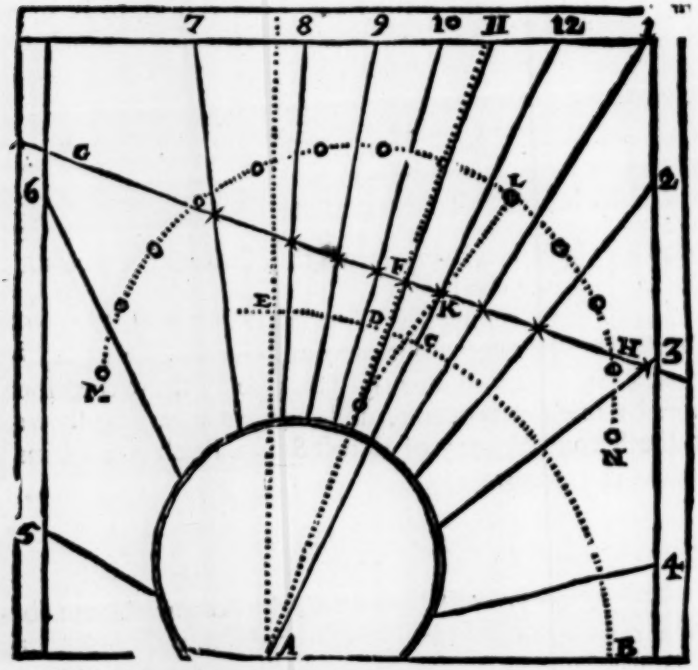
Theſe requiſites being thus found, you may proceed to draw the hour-lines in this as in other Plains. Firſt, by laying a Ruler upon P the Pole of the World, to B, in the interſection of the *Meridian* and *Æquinoctial*, which will cut the Plain in *k*, at which point, begin to divide the Semicircle into 12 equal parts. And from Q, to each of them, lay a Ruler croſſing the *Æquinoctial* Circle, and dividing that into 12 unequal parts, to which unequal parts of the *Æquinoctial*, a Ruler laid, it will divide the Plain into 12 other unequal parts, through which, and the Centre Q, right lines being drawn, they ſhall be the true hour-lines proper for the Plain.

But in this Example, the Elevation of the Pole or Stile above the Plain, being but of an indifferent Elevation, *viz.* 19 deg. 25 min. you may (if you pleaſe) draw the Hour-lines by one Tangent line, and the Centre, as was ſhewed in the Second Variety of Direct South Reclining Plains; and as here followeth.

How to draw the Hour-lines upon the Plain.

Firſt, Upon your Plain, towards the bottom thereof (becauſe the North Pole is here elevated) draw a right line A B, parallel to the *Horizon*, and aſſume A for the Centre of your Dial, upon which point, with 60 deg. of your Chord, deſcribe an Arch of a Circle B E, upon which from B, ſet the diſtance of the *Meridian* and *Horizon*, 64 deg. 41 min. to C, and draw the line A C for the Hour-line of 12. Alſo, upon the ſame Arch from C to D, ſet 6 deg. 2 min. the diſtance of the Subſtile from the *Meridian*; and draw the line A D for the Subſtilar. Again, upon the ſame Arch, ſet off 19 deg. 25 min the height of the Stile from D to E, and draw the Line D E for the Axis of the Stile.

A South Plain Declining Eaſtward 30 *deg. and Reclining* 55 *deg.*



Secondly, Upon any part of the Snbſtilar Line, aſſume any point at pleaſure. As F, through which draw the right line G F H perpendicular to the Subſtile.

Thirdly, From the point F, take the neareſt diſtance to the Axis of the Stile, and ſet that diſtance upon the Subſtilar Line from F to O, and upon the point O with 60 deg. of your Chord, deſcribe the Semicircle M L N.

Fourthly, Lay a Ruler from O to K (the point where the Tangent (or *Æquinoctial* line) croſſeth the *Meridian*) and the Ruler will cut the Semicircle in L, at which pointbegin

gin to divide it into 12 equal parts in the points ⊙ ⊙ ⊙ *&c.*

Fifthly, Lay a Ruler from O the Centre of the Semicircle to the ſeveral points ⊙ ⊙ ⊙ in the Semicircle, and the Ruler will cut the Tangent line in the points *** *&c.*

Laſtly, If from the Centre A, through theſe points *** *&c.* you draw right-lines, they ſhall be the proper Hour-lines belonging to your Plain.

For the Stile it may be either of Plate or Wire, elevated above the Subſtile to an Angle of 19 deg. 25 min. and ſet up perpendicularly upon the Subſtilar, as in all other Dials. And thus have I done with all the Varieties of South Declining Reclining Plains.

II. *Of North Recliners.*

The Firſt Variety.

CHAP. XXIII.

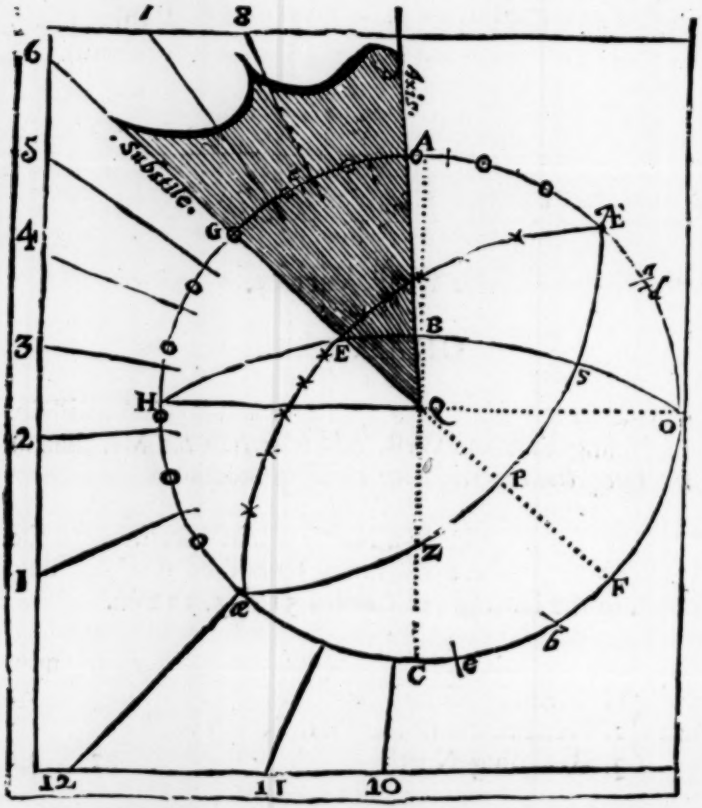
How to draw the Hour-lines upon a North Reclining Plain, Declining Eaſt or Weſt, *which cutteth the* Meridian *at the Interſection thereof with the* Æquinoctial.

LEt the Example be of a North Plain Declining to the Weſt 60 deg. and Reclining from the Zenith 32 deg. 11 min. in the Latitude of *London* 51 deg. 32 min.

		deg.	min.
Data	1. Latitude of the Place	51	32
	2. Declination of the Plain North Weſt	60	00
	3. Reclining North	32	11

Quæſita
1. The diſtance of the Meridian and Horizon.
2. The height of the Pole or Stile above the Plain.
3. The diſtance of the Subſtile and the Meridian.
4. the Plains difference of Longitude.

		deg.	min.
North	*Declining Weſt*	60	00
	Reclining	32	11



Firſt, Deſcribe the Circle A H C O, for the Declining Re-

Reclining Plain; croſs it at right Angles with the two Diameters H O for the Horizontal, and A C for the Vertical line of the plain.

And here for Variety, more than for neceſſity, in theſe three following Examples of North Recliners Declining, I will (in the ſeveral Schemes) place the Zenith and pole down wards, becauſe the Stile in all theſe Dials muſt point upwards, the North pole being always elevated, and in ſo doing, the Hour-lines, Stile and Subſtile will ſtand in the Scheme as they are to ſtand in the Dial. and the manner of Work will be the ſame as before. Wherefore,

Secondly, Set 32 deg. 11 min. the plains Reclination, from O to *a*, and from C to *b*. A Ruler laid from H to *a*, ſhall give you the point B, through which, and the points H and O, the Horizon H B O is to be deſcribed. And a Ruler laid from H to *b*, ſhall give you Z the Zenith point.

Thirdly, Set 60 deg. the plains Declination from A to *d*, a Ruler laid from Z the Zenith, to *d*, ſhall cut the Horizon in S the South point thereof. Thus have you two points Z and S, through which to draw the Meridian, whoſe Centre will be in the line Q E extended, and may be found as formerly is taught.

Fourthly, The Horizon and Meridian being thus drawn, lay a Ruler from E to Z, and it will cut the Plain in *e*, and ſeeing the pole is 38 deg. 28 min. diſtant from the Zenith, ſet 38 deg. 28 min. from *e* to F, and a Ruler laid from E to F, will cut the Meridian in P the Pole of the World, through which point P, and the Centre Q, draw the line P Q for the Axis of the World, and Subſtile of the Dial. And again, becauſe the Æquinoctial is 90 deg. from the Pole, ſet 90 deg. from F, and they will reach juſt to Æ or *æ* on either ſide, which are the very points that the plain cuts the Meridian in, and through which points, and the pont E, in the Horizon, the Æquinoctial Circle muſt paſs; whoſe Centre will always be in the the Axis of the World P Q extended.

The

The *Horizon*, *Meridian* and *Æquinoctial* being thus drawn, you may find the four Requiſites in this manner.

1. *To find the diſtance of the Meridian from the Horizon* Æ O. The Arch Æ O meaſured by your Line of Chords, will be found to contain 47 deg. 18 min. which is the Subſtiles diſtance from the Meridian.
2. *To find the height of the Pole or Stile above the Plain* P F. A Ruler laid from æ to P, will cut the Plain in O, ſo the diſtance F O 42 deg. 52 min. is the height of the pole above the Plain.
3. *The diſtance of the Subſtile from the Meridian* æ G, which meaſured upon your Chord, will be found to contain juſt 90 deg.
4. *The Plains difference of Longitude* G P æ, *or the Arch* æ G, as before alſo 90 deg. juſt.

In this Scheme two things are remarkable.

1. The Plains cutting the Meridian in its interſection, with the Æquinoctial. And,
2. The Axis of the World paſſing through the Eaſt point of the *Horizon*, both which denote the Plain to be polar Declining, and the Subſtile to be the ſame with the Hour-line of 6. And the Hour-line of 12 at right Angles thereto, wherefore the Hour-lines may be drawn, as followeth.

To draw the Hour-lines upon the Plain.

Firſt, Lay a Ruler from P to Æ, where the *Meridian* and *Æquinoctial* interſect, which is upon the plain at the very point Æ, wherefore there begin to divide the Semicircle Æ G æ, into 12 equal parts at the points ⊙ ⊙ ⊙ *&c.*

Secondly, Lay a Ruler to Q, and every of the points ⊙ ⊙ ⊙ *&c.* and it will cut the Æquinoctial in the points *** *&c.* dividing that into 12 unequal parts.

Thirdly, A Ruler laid to P, and the ſeveral points *** *&c.* in the Æquinoctial, will cut the plain in the marks ||| *&c.*

Laſtly,

Laſtly, A Ruler laid from Q to the ſeveral marks ||| *&c.* and ſtrait lines drawn thereby, ſhall be the true Hour-lines fitting this polar Decling Plain.

For the Stile, it muſt be a Plate or Wire ſet upright upon the Subſtilar to an Angle of 42 deg. 52 min. and muſt point upwards to the North Pole.

The Second Variety.

CHAP. XXIV.

How to draw the Hour-lines *upon a* North Reclining Plain, Declining Eaſt or Weſt, *the Plain paſſing through the* Meridian, *between the* Zenith *and the* Æquinoctial.

IN this (as in the former Examples) three things muſt be given, and four found, before the Hour-lines can be drawn.

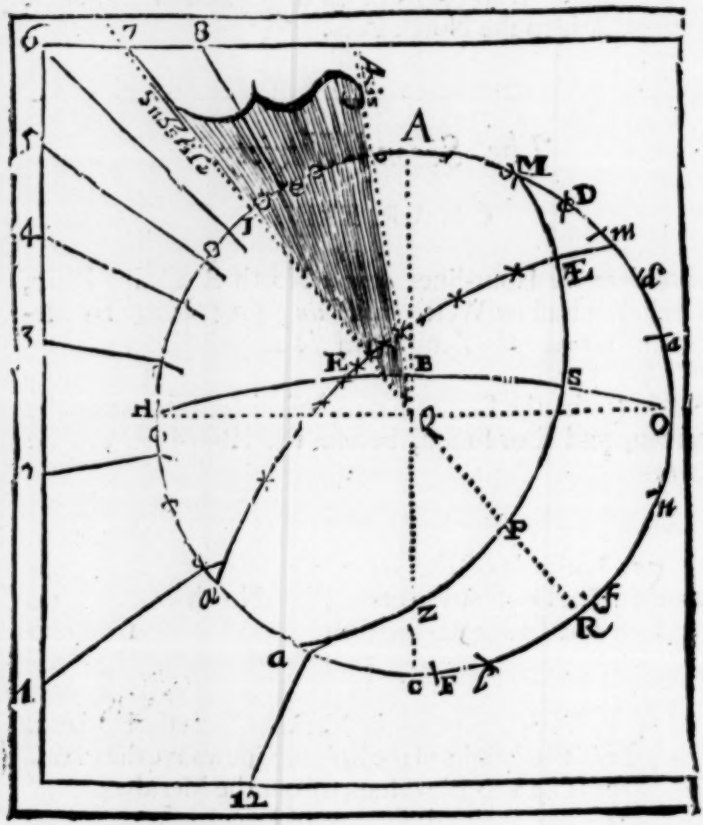
		deg.	min.
Data	1. Latitude of the place	51	32
	2. The Declination of the Plain North W.	60	∞
	3. The Plains Reclination	16	∞

Quæſita
1. The diſtance of the Meridian from the Horizon.
2. The height of the Pole or Stile above the Plain.
3. The Subſtile diſtance from the Meridian.
4. The Plains difference of Longitude.

Firſt, Deſcribe the Circle A H C O for the plain, and croſs it with the Diameters A C, and H O, for the Horizontal and Virtical lines thereof.

Secondly, (As in the laſt Example,) ſet 16 deg. the Plains Recli-

A North Dial { *Declining Weſt* 60
{ *Reclining* 16



Reclination, from O to *a*, and from C to *b*, a Ruler laid from H to *a*, ſhall give the point B. through which, and the points H and O, the Horizontal Circle H B O is to be deſcribed. Alſo a Ruler laid from H to *b*, ſhall find the Zenith point of Z.

Thirdly,

Thirdly, Set the plains Declination 60 deg. from A to *d*, and from H to *e*: So a Ruler laid from Z to *d*, ſhall cut the Horizon in S the South, and laid from Z to *e*, ſhall cut it in E the Eaſt point thereof; and now having two points Z and S, through them you may draw the *Meridian* Circle, as hath been already taught.

Fourthly, Lay a Ruler from E to Z, it will cut the Plain in F, and 30 deg. 28 min. the Complement of the Latitude of the place, ſet from F to *f*, and a Ruler laid from E to *f*, will cut the *Meridian* in P the pole of the World, and 90 d. more, being ſet forward from *f* to *m*, and a Ruler laid from E to *m*, will cut the *Meridian* in Æ, the Æquinoctials interſection with the *Meridian*; ſo have you two points Æ and E, through which the *Æquinoctial* Circle muſt paſs, and a right line drawn through P the pole of the World, and Q the pole of the Plain, will be the Axis of the World, and the Subſtilar line of the Dial.

Theſe three Circles, *viz.* the *Horizon*, *Meridian*, and *Æquinoctial* being deſcribed, the fore-mentioned four Requiſites may from thence be eaſily obtained. For,

1. *The diſtance of the Meridian from the Horizon*, is the Arch F H, 64 deg. 29 min.
2. *The height of the Pole or Stile above the Plain* P R. A Ruler laid from *æ* to P, will cut the plain in *n*: So the diſtance R *n* meaſured, will be found to be 30 d. 59 min.
3. *The Subſtiles diſtance from the Meridian* is the Arch I M, 64 deg. 26 min.
4. *The Plains difference of Longitude* is the Angle Æ P Q, which to find, lay a Ruler from P to Æ; and it will cut the plain in D, the diſtance D I meaſured upon the Line of Chords, will give 76 deg. 10 min. for the Plains difference of Longitude.

To draw the Hour-lines upon the Plain.

Firſt, Lay a Ruler upon P the Pole of the World, and Æ, the interſection of the Meridian with the Horizon, and it will cut the plain in D, at which point begin to divide the Semicircle *e I m* into 12 equal parts, at the points ⊙ ⊙ ⊙ *&c.*

Secondly, Lay a Ruler from Q to the ſeveral points ⊙ ⊙ ⊙ *&c.* and it will divide the Æquinoctial Circle into 12 unequal parts in the points *** *&c.*

Thirdly, A Ruler laid from P to every of theſe unequal parts *** *&c.* will cut the plain in theſe marks ||| *&c.* dividing that into 12 other unequal parts.

Laſtly, If you draw right lines from Q, through every of theſe marks ||| *&c.* they ſhall be the true Hour-lines belonging to your Plain.

The Stile may be either of Wire or Plate as in other Dials, and muſt be elevated above the Subſtile, to an Angle of 30 deg. 59 min. and muſt ſtand ſquare, or at Right Angles to the plain.

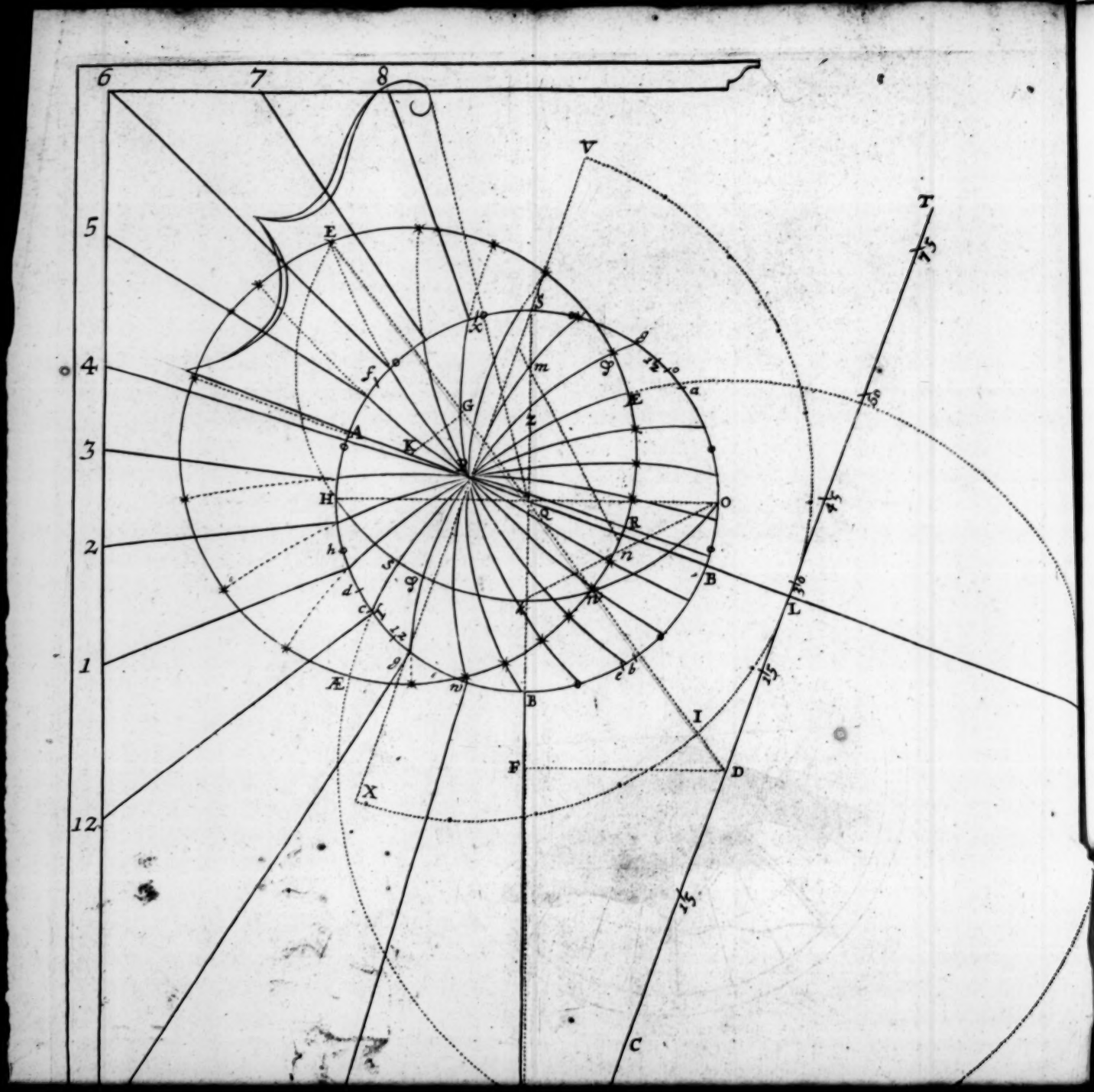
The Third Variety.

CHAP. XXV.

How to draw the Hour-lines upon a North Reclining, *or* Inclining Plain, Declining Eaſt *or* Weſt, *which interſects the* Meridian *between the* Æquinoctial *and the* Horizon.

LEt this third and laſt Example of North Recliners Declining, be of a North Plain, Reclining 54 deg. and Declining Weſtward 60 deg. in the Latitude of *London* 51 deg. 32 min.

This being the third and laſt Variety of Declining Reclining plains, I ſhall be ſomewhat the larger in the projection thereof, than I have been in any of the foregoing; not but


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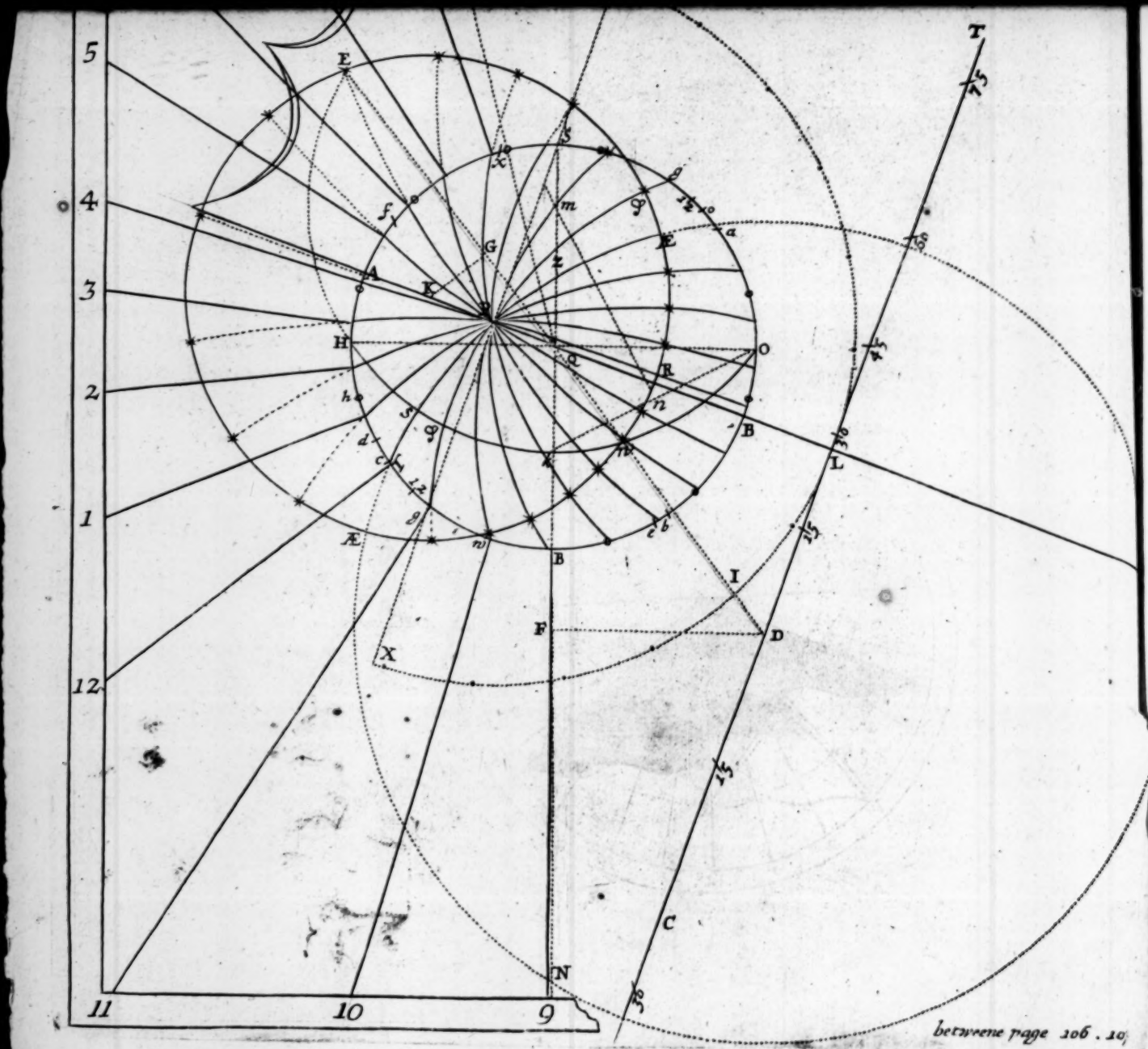
but that this Dial is to be made in all reſpects like (and with the ſame eaſe) as the former. But herein I ſhall ſhew at large the manner of projection, and how all the Centres are Geometrically found, and the reaſons of their being in ſuch and ſuch lines, and at ſuch and ſuch diſtances. And alſo, I ſhall project all the Hour-lines belonging to the Plain upon the Plain it ſelf by circular Lines, by which means the Reader may attain to a more competent knowledge in what hath been heretofore in this Treatiſe delivered. For from this projection following, all the aforeſaid hath been deduced. And therefore I ſhall deſcribe the manner of the delineating of this Dial, according to the following *Propoſition.*

PROPOSITION.

A Circle being deſcribed, repreſenting a Declining Reclining Dial-Plain; how thereon to place the Meridian, Horizon, Æquinoctial, Pole, Zenith, *&c. with all other* Requiſites *belonging to ſuch a Dial. And alſo, to project the* Meridians *of the* Sphere *it ſelf upon the* Plain, *and from thence to draw the* Hour-lines *upon the* Dial-plain, *according to their true Situation.*

LEt the Circle H S O B, repreſent a Dial-plain in the Latitude of *London* 51 deg. 32 min. Declining from the North towards the Weſt 60 deg. 00 min. and Reclining from the Zenith Northward 54 deg. 00 min.

Firſt, Croſs the Circle with the two Diameters H O, and S B, cutting each other at Right Angles in the Centre Q. And becauſe the plain reclineth 54 deg. 30 min. take 54 deg. 30 min. out of your Line of Chords, and ſet that diſtance upon your plain, frm S to *a*, from O to *b*, and from B to *c*: Then lay a Ruler from H to *a*, and it will cut



betwreene page 106 . 10

and ſuch lines, and at ſuch and ſuch diſtances. And alſo, I ſhall project all the Hour-lines belonging to the Plain upon the Plain it ſelf by circular Lines, by which means the Reader may attain to a more competent knowledge in what hath been heretofore in this Treatiſe delivered. For from this projection following, all the aforeſaid hath been deduced. And therefore I ſhall deſcribe the manner of the delineating of this Dial, according to the following *Propoſition.*

PROPOSITION.

A Circle being deſcribed, repreſenting a Declining Reclining Dial-Plain; how thereon to place the Meridian, Horizon, Æquinoctial, Pole, Zenith, *&c. with all other* Requiſites *belonging to ſuch a Dial. And alſo, to project the* Meridians *of the* Sphere *it ſelf upon the* Plain, *and from thence to draw the* Hour-lines *upon the* Dial-plain, *according to their true Situation.*

LEt the Circle H S O B, repreſent a Dial-plain in the Latitude of *London* 51 deg. 32 min. Declining from the North towards the Weſt 60 deg. 00 min. and Reclining from the Zenith Northward 54 deg. 00 min.

Firſt, Croſs the Circle with the two Diameters H O, and S B, cutting each other at Right Angles in the Centre Q. And becauſe the plain reclineth 54 deg. 30 min. take 54 deg. 30 min. out of your Line of Chords, and ſet that diſtance upon your plain, frm S to *a*, from O to *b*, and from B to *c*: Then lay a Ruler from H to *a*, and it will cut

the Line S B in Z, ſo ſhall the point Z be the Zenith of the place.

Secondly, Lay a Ruler from H to *b*, it will cut the Line S B in *k*, ſo ſhall *k* be a point in the line S B, through which the Horizon ſhall paſs: And thus having three points H *k* O, you may through them deſcribe the Horizon, whoſe Centre will be at *m*, the diſtance *m k* being equal to the Secant of the Complement of the Reclination of the Plain; namely, 36 deg. —— Or Geometrically thus. Draw the right line *k* O, which divide into two equal parts in *n*, and upon the point *n*, raiſe a perpendicular *n m*, extending it till it cut the line S B in *m*, ſo ſhall *m* be the Centre of the Horizontal Circle H *k* O.

Thirdly, Lay a Ruler from H to *c*, it will cut the line S B (being extended) in the point N, ſo ſhall N be the Nadir point.

Fourthly, Becauſe the Plain declines 60 deg. from the North Weſtward; ſet 60 deg. from B to *d*, and laying a Ruler to Z the Zenith, (which is alſo the Pole of the Horizon) to *d*, it will cut the Horizon in S, through which point the *Meridian* muſt paſs.

Fifthly, Take (always) 90 deg. of your Chord, and ſet that diſtance from *d* to *e*, and laying a Ruler from Z to *e*, it will cut the Horizon in W the Weſt point thereof, and a line drawn from W, through Q the Centre of your plain, will cut the Horizon (if you extend it as here is done) in E, the Eaſt point thereof, and in ſome part of this line (extended if need require) will the Centre of the Meridian be; and where that point will fall may be thus found,

Sixthly, Divide the line Z N into two equal parts in F, and upon F erect the perpendicular F D, cutting the Line Q W (extended) in D, ſo ſhall D be the Centre of the Meridian of the place.

Seventhly, If with your Compaſſes you take the diſtance D P, and with that extent upon D, as a Centre, deſcribe a Circle, you ſhall find that Circle exactly to paſs through the reſpective points Z and N, if there be no former errour committed in your work.

Eighthly,

Eighthly, Becauſe the height of the Pole above the Horizon, is equal to the Latitude of the place, *viz.* at *London* 51 deg. 32 min. ſet off 51 deg. 32 min. upon the *Meridian* from S to P, in this manner.

Ninthly, Lay a Ruler from W, the Weſt point of the Horizon, (which is alſo the Pole of the *Meridian*) to S and it will cut the Plain in *h*, then ſet 51 deg 32 min. from *h* to *f*. A Ruler laid from W to *f*, it will cut the *Meridian* in P, ſo is P the Pole of the World, diſtant from Z the Zenith, 38 deg. 28 min. and a Line drawn through P the Pole of the World, and Q the Centre of the Plain, will be the Axis of the World, and (extended) will cut the *Meridian* in M the South Pole.

Tenthly, The *Meridian* and *Horizon* being thus drawn, it is eaſie to deſcribe the *Æquinoctial*, for if you conſider the poſition of that Circle in the Sphere it ſelf, you know that it always paſſes through the Eaſt and Weſt points of the *Horizon*, and cutteth the *Meridian* at right angles, it being in all places 90 deg. diſtant from either of the Poles. Wherefore, if upon W, (the Pole of the *Meridian*) you lay a Ruler to P, the Pole of the World, it will cut the Plain in *f*, and if you ſet 90 deg from *f* to *g*, and lay a Ruler from W to *g*, it will cut the *Meridian* in Æ, ſo have you three points, through which the Æquinoctial muſt paſs, namely E Æ and W, and the Centre of the Æquinoctial will always be in the Axis of the World, extended if need require. To find which, you muſt,

Eleventhly, Divide the Line W E into two equal parts in G, and from the point G, upon the line E W, erect the perpendicular G K, cutting the Axis of the World in K, ſo ſhall K be the Centre of the Æquinoctial, wherefore, if upon K as a Centre, with the diſtance K W, you deſcribe a Circle, that ſhall be the Æquinoctial, and (if your work be true) ſhall paſs through the points E Æ and W: Then for the dividing of the Æquinoctial,

Twelfthly,

Twelfthly, Lay a Ruler to P the pole of the World, (which is alſo the pole of the Æquinoctial) to Æ, the interſection of the Meridian and Æquinoctial, and it will cut the plain in the point 12 at which point you muſt begin to divide the Circle repreſenting your Reclining Declining plain into 24 equal parts at the points ⊙ ⊙ ⊙ *&c.* This done, lay the Ruler to the point P, and every of the 24 equal parts ⊙ ⊙ ⊙, and you ſhall find it to cut the Æquinoctial Circle in the points * * * * *&c.* dividing that Circle into 24 unequal parts, through which unequal parts, and the two poles of the World P and M, muſt all the Hour-Circles paſs. For the deſcribing whereof you muſt,

Thirteenthly, Divide the line P M into two equal parts in the point L, [or, from the point D, the Centre of the Meridian, let fall a perpendicular upon the Axis of the World, which will fall in the ſame point L,] and through the point L, draw an infinite right line at right angles to P M, namely, the Line C T, for in that line will the Centres of all the Hour-circles be found, and the manner how to find them, is thus (one way) to be effected.

Fourteenthly, Upon the point P as a Centre, at the diſtance *P* L, [or to any other Radius of a Line of Chords] deſcribe the Semicircle X L V, and divide it into 12 equal parts at the points · · · · *&c.* beginning your diviſion at the point J, which is, where the Ruler being laid from *P* to D (the Centre of the Meridian) cuts this laſt drawn Circle. Then laying a Ruler from *P*, upon each of theſe diviſions, you ſhall find it to cut the line C T in the points 15, 30, 45, 60, *&c.* on either ſide of the point D. And here note, that 15 is the Centre of the firſt hours diſtance from the *Meridian* on either ſide thereof, 30 the Centre of the ſecond, and 45 of the third hours diſtance from the *Meridian*, *&c.*

Fifteenthly, If you place one foot of your Compaſſes upon 15, and extend the other to *P* the Pole of the World, and with that diſtance deſcribe a Circle, that Circle ſhall be the

the firſt hour from the *Meridian*, and (if your work be true) ſhall paſs through M the South Pole, and alſo through φ φ, the two firſt unequal diviſions of the Æquinoctial Circle, and ſo all the reſt.

Laſtly, If from Q the Centre of your Plain, and the reſpective points where the Hour-circles cut the Plain, you draw ſtrait lines, thoſe ſhall be the true Hour-lines proper for ſuch a Declination and Reclination, as you formed your projection for.

Now the Requiſites belonging to this, and the like Declining Reclining Plains, are,

			deg.	min.
1. The height of the Pole above the Plain.	represented by	P A	54	43
2. The diſtance of the Meridian and Horizon.		H Γ	53	31
3. The diſtance of the Subſtile from the Meridian.		Γ A	56	41
4. The Angle between the two Meridians.		Æ P R	61	47

All which may be meaſured upon the projection, and ſo their quantities found. As,

1. To find P A, Lay a Ruler from P to ϖ, where the *Æquinoctial* and the plain do interſect, and the Ruler will cut the plain on the other ſide at *x*, ſo A *x* meaſured upon the Line of Chords, will be 54 d. 43 m. the height of the pole above the Plain, [or P Q meaſured upon a line of half Tangents, will contain 35 d. 17 min.] the Complement thereof.
2. To find H Γ, the arch H Γ meaſured upon the Line of Chords, will give 53 deg. 31 min. the diſtance of the Meridian from the Horizon.
3. To find Γ A, the Arch Γ A meaſured upon the Line of Chords,

Chords, will give 56 deg. 41 min. the diſtance of the Subſtile from the Meridian

4. To find Æ P Q, Lay a Ruler to P the Pole of the World, and Æ the interſection of the Meridian and the Æquinoctial, and it will cut the plain in θ, the arch θ B, meaſured upon the Line of Chords, will be found to contain 61 deg. 47 min. which is the Angle between the two Meridians.

Thus have you in this Scheme delivered the true and genuine way of delineating of Sun Dials deduced from the Sphere it ſelf, by which the reaſon of all that hath been before delivered, is rendred obvious, and ſufficiently demonſtrative for this place. But here you ſee that the Centres of the Meridians or Hour-circles fall out to be very remote, and that there will be required a large Tangent line for their deſcription, which will (for the moſt part) run out very far, and ſometimes, almoſt to an infinite excurſion. I therefore choſe rather to ſhew how the Hour-lines might be drawn without having any regard to this Tangent line, or without projecting of the Hour-lines upon the Circular-plain, and therefore the ways before delivered are far more apt for practice than this, though this be more ſatisfactory to the inquiſitive Reader, who will not be ſatisfied only with the doing, but of the underſtanding as well of what he does, and it is for the ſatisfaction of ſuch, that I have here added this Propoſition.

CHAP. XXVII.

Concerning Inclining Plains, both Direct and Declining.

OF Reclining Plains there are but two ſorts, as hath been before inſtanced, and thoſe are either *Direct* or *Declining*. The Direct are thoſe Reclining Plains which do directly behold the *Eaſt*, *Weſt*, *North*, or *South* points of the Horizon.

Horizon. And the *Decliners* are thoſe which (beſides their Reclination from the Zenith) do reſpect two of the forementioned Cardinal points, as,

(1.) The *South* and the *Weſt*.
(2.) The *North* and the *Weſt*.
(3.) The *South* and the *Eaſt*.
Or, (4.) The *North* and the *Eaſt*.

The	First, Second, Third, Fourth	ſort are called	South, North, South, North	declining Weſt, declining Eaſt	Reclining

I alſo before intimated, and gave Examples, that of direct Recliners, there were three ſorts, *viz.*

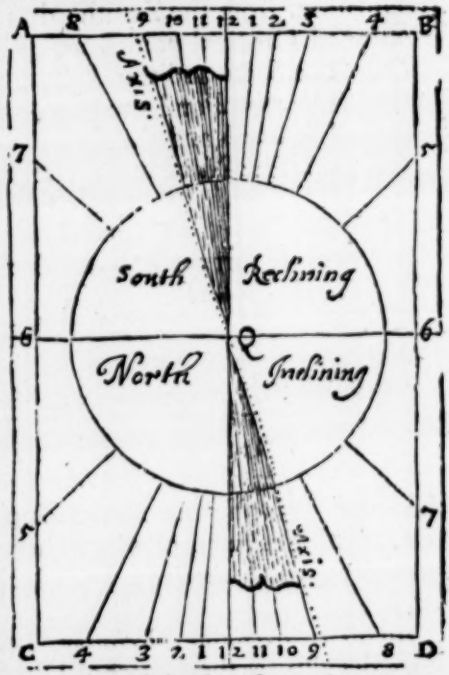
1. Such as Reclining from the Zenith, do behold either the due *Eaſt*, or due *Weſt* points of the Horizon; and of this ſort there is only one kind, and no Variety in any caſe.----

2. *South Recliners*, of which there are three Varieties.----

And 3. *North Recliners*, of which alſo there are three Varieties.

Again, of *Reclining Declining*, I told you there were ſix Varieties alſo, as there were of Direct Recliners, *viz.* Three of South Declining Plains Reclining, and as many of North Reclining Declining Plains; of all which I have given Examples, and it may be now expected that I ſhould do the like for the Inclining Plains oppoſite to them, of which there are alſo as many Varieties, but ſeeing that the making of the Reclining Dial, whether Direct or Declining doth alſo make the Inclining Dial, whether Direct or Declining oppoſite thereunto, I ſhall ſave the labour, and commend to the ingenious Reader ſome few Rules by which he ſhall eaſily frame the Inclining Dial out of the Recliner. And,

I. *Of North and South Inclivers.*



I will take for Example a South Plain Reclining 55 deg. which is the Third Variety of South Recliners, and I would from that deduce the Hour-lines proper for a North plain Inclining as much, *viz.* 55 deg. And it is easily effected. For,

If you draw the Hour-lines of the South Recliner *6* A B *6*, and the Stile thereof also, quite through the Centre Q, to the opposite part of the Plain, *6* C D *6*, and set the same numbers to the hours on the right hand in the Recliner, and the contrary, as the Figure clearly demonstrates: And let the Axis in the North Incliner point downwards to the South Pole, as the Axis in the South Recliner doth upwards to the North Pole, and your Dial is finished. Or you may effect this work by pricking off the Hour-lines through the Paper, and turning it upside down, and that will effect the same thing, only changing of the names of the hours. Or again, if you turn the South Reclining Plain, *6* A B *6* about, upon the Centre Q, till the Line A B come to be in the place of C D, then will the Hours, Stile and all, be truly named and posited; and the very South Recliner will now become the North Incliner without any Alteration.

II *Of*

II. *Of East and West Incliners.*

There is little difference in drawing of the East or West Inclining Dials from the Reclining Dials oppoſite to them, than there was of drawing of the North Incliner before, from the South Recliner. For,

In the Example of the East and West Reclining and Inclining Dial, before going Chapter 10. The Dial as it there ſtands, repreſents an East or West Reclining Plain. But if you turn the Dial about upon the Centre Q, till the letter N come to be in the place of the letter S, in that Figure, then will the ſame Dial repreſent both an East and West Dial Inclining 35 deg. as now it doth an East or West Reclining as much. The Subſtile, Stile, Meridian, and the reſt of the Hour-lines retaining the ſame names or denominations, as now they do.

III. *Of North or South Declining Inclining Plains.*

Of North and South Reclining Declining Plains, there were Six Varieties, Examples of each have been largely given. There are as many of North and South Incliners, but ſeeing they may be ſo eaſily deduced out of their oppoſite Recliners, I ſhall forbear giving examples, and the way is not much differing from the Rules before given for Direct Reclining and Inclining Plains. For ſeeing the Reclination is alike proper to each, and the Deflexion of the Subſtile from the Meridian in the Declinations do ſo directly agree, they may both be reduced to one and the ſame Dial as the other were.

Thus, If any Reclining Dial be ſo inverted, that the upper part thereof, become the nether, and after this inverſion the right ſide of the Recliner, become the left ſide of the Incliner, and the contrary, the Inclining Dial having the ſame declination, ſhall be framed out of the Recliner, and the contrary. Only the denominations of the Hours muſt be changed. For the Forenoon hours in the Recliner, will be the Afternoon hours in the Incliner, and the Afternoon hours of the upper Dial, the Forenoon hours of the nether.

CHAP. XXVIII.

A General Rule to know which Pole, *whether the* North *or the* South *is to be elevated over any* Plain.

THe Stile of every Dial reſpecteth (or rather lieth parallel with) the Axis of the World, and always pointeth upwards or downwards, to one of the Poles. Now when you have drawn your Dial (though truly) you may be to ſeek, whether it it be the North or the South Pole that muſt be elevated; wherefore to avoid any miſtake, and to inform you which Pole is to be elevated. Obſerve this General Rule.

Upon all Upright Plains, whether direct or declining, upon the { South / North } ſide the { South / North } Pole.

Upon all Eaſt and Weſt { Recliners / Incliners } the { North / South } Pole.

Upon all { North Recliners / South Incliners } { whether Direct or Declining } { North / South } Pole.

Upon all { South Recliners / North Incliners } { whether direct or declining } { If the Plain paſs between the } { Zenith / Nadir / Horizon } { and the Pole, the } { South / North / South } Pole.

This Rule being duly obſerved, there will be no difficulty to find which Pole is elevated.

A Second

A Second Way OF DIALLING, *GEOMETRICALLY* Performed.

PART II.

IN the foregoing First Part, you have a moſt abſolute and perfect way of delineating of *Sun-Dials* upon all ſorts of *Plain Superficies* in what poſition ſoever ſituate, and in any Latitude, whether the Plains be *Direct*, or do *Decline*, or whether they both *Decline* or *Recline*: And alſo you may there find, not only the manner how to make *Dials*, but to know the *Grounds* and *Reaſon* of *Dials*, deduced from the *Sphere* or *Globe* projected *in plano*, upon the *Dial-Plains Superficies*.

But notwithſtanding the Exactneſs and Rationality of delineating of Hour-lines upon all *Plains*, and in all Places, as is before taught; yet the ways there delivered, may (in ſome caſes, at ſome times) be found inconvenient to put in practice: As (1.) When the *Centres* of ſome of the *Circles* fall out to be very remote.

(2) When

(2) When the unequal Diviſions of the *Æquinoctial* Circle come very near or cloſe together, which they will always do, when the Pole hath but ſmall Elevation above the Plain, and ſuch like. For the removal of which Inconveniencies, I ſhall in this *Second Part* add another *Geometrical Way of Dialling*, which ſhall be both Plain, Eaſie, Exact, and of Quick diſpatch; and all of it performed by ſtrait Lines, and not by Circular Lines, as the former way requires. And moreover, this *Second Way* hath a Convenience, which moſt other *Geometrical* ways of *Dialling* are culpable of, namely, to out-run the Limits of the Plain, by almoſt infinite Excurſions: For in this way, having firſt made a *Preparative Scheme* upon Paper (or Paſtboard rather) you ſhall have very few Lines to draw upon the Dial-plain but the Hour-lines themſelves.

In this *Second Way*, I ſhall be brief, beginning firſt to ſhew how to deſcribe the Hour-lines upon *Upright Declining Plains*; referring the delineation of Hours upon the *Horizontal full North, South, Eaſt* and *Weſt Plains* (whether Upright or Reclining) till afterwards: And the Reaſon for my ſo doing, will of it ſelf appear, when I ſhall come to treat of them. Wherefore to proceed,

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Section I.

How to draw Hour-lines upon an Upright South Plain Declining from the South towards the Weſt 20 *deg. in the Latitude of* London 51 *deg.* 32 *min.*

HAving the *Latitude of the Place*, and the *Declination of your Plain* given, before you come to draw the Hour-lines upon the Plain, you muſt firſt draw your *Preparative Scheme*, as followeth.

I. *How*

I. *How to draw a* Preparative Scheme *ſuitable to any Declination in any Latitude.*

Firſt, With 60 deg. or the Radius of your Scale of Chords, deſcribe the Quadrant of a Circle A B D, extending the ſide B A to C, ſo that A C be equal to A B: And then draw the right line D C.

Secondly, On the point B, erect the perpendicular B *m*.

Thirdly, Take 51 deg. 30 min. (the Latitude) out of your Scale of Chords, and ſet them from B to F, and from D to G, and laying a Ruler from A, to F and G, draw the two Lines F K, and G I.

Fourthly, From the point G, draw the Line G H, parallel to D A, or perpendicular to B A.

Fifthly, Take 20 deg. (the Plains Declination) out of your Scale of Chords, and ſet them from D to E, and through the point E, draw the Line E L, parallel to D A.

Sixthly, With 60 deg. (or the Radius of your Scale of Chords) taken in your Compaſſes, ſet one foot in the point D, and with the other deſcribe the Arch A O, which divide into three equal parts, in the points P and Q, for the whole hours, each of which three Hour-ſpaces A P, P Q, and Q O, divide into four equal parts at ***, ***, ***, for halfs and quarters of hours. Which done, if you lay a Ruler to the point D, and the points P and Q, the Ruler will cut the Line A C in the points 2 10, and 1 11, and by theſe points the Line A C is divided into four unequal parts in the points 39, 2 10, 1 11 and 12, repreſenting three hours. And if from D, you lay a Ruler over the ſeveral points *** *&c.* they ſhall divide the ſeveral ſpaces in the Hour-line A C into four unequal parts for halfs and Quarters of Hours. And thus is your *Preparative Scheme* ſo far finiſhed. Wherefore now let us proceed,

II. *To*

II. *To draw the Meridian, Stile, Subſtile, and Hour-lines upon the Plain it ſelf.*

Firſt, Upon your Dial-plain, draw a Right Line as S T, for the *Meridian*, and Hour-line of 12. Upon which, aſſign any convenient point, as R, for the Centre of your Dial; through which point R, draw the Line R W, perpendicular to S T.

Secondly, Out of your *Preparative Scheme* take the Line B K, and ſet it upon your Dial-plain, from R to T; alſo, from the *Preparative Scheme*, take B I, and ſet it on your Dial-plain from R to W, on the right hand, becauſe the Plain declineth Weſt, and from T to V, make the Rectangled Parallelogram R W T V on the Eaſt ſide.

Thirdly, Out of the *Preparative Scheme*, take the Line L A, and ſet it upon the Dial-plain from T to X, and from W to ⊖, and draw the Lines R X for the Subſtilar Line, and R ⊖ for the Hour-line of Six, which draw quite through the Centre R.

Fourthly, Out of your *Preparative Scheme*, take the Line E L, and ſet it upon your Dial-plain from R to 12, and from X to Y, perpendicular to R X, and draw the Line R Y for the Axis (or Stile of your Dial.)

Fifthly, Out of your *Preparative Scheme*, take the line G H, and ſet it on your Dial-plain from R to Z, and draw the line Z 6, parallel to W Y, till it cut the Hour-line of Six in 6.

Sixthly, Make R 6 above the Centre, equal to R 6 below the Centre, and draw the two Lines 12 6, and 12 6.

Seventhly, Out of your *Dial-plain*, take the length of the Lines 12 6, and 12 6, and ſet them upon the *Preparative Scheme* from B to *b*, and from B to *a*. And laying a Ruler from C to *a*, draw the Lines M C, and N C.

Laſtly, From the point A or 3, 9, take the neareſt diſtance to the Line N C, and ſet that diſtance upon your *Dial-plain* from

from 12 to 9, or from 6 to 9, for it will (if you work truly) divide the Line 6, 12 into two equal parts in 9. Alſo ſet one foot of the Compaſſes in the point 2, 10 in the Line A C of the *Preparative Scheme*, with the other take the neareſt diſtance to the Line N C, and ſet that diſtance upon your *Dial-plain*, from 12 to 8, and from 6 to 10. ----- Again, ſetting one foot of the Compaſſes in the point 1, 11, in the Line A C of the *Preparative Scheme*, with the other, take the neareſt diſtance to the Line N C, and ſet that diſtance from 12 to 11, and from 6 to 7. So is the longer Line 6, 12 on your *Dial-plain*, divided into Six unequal parts in the points 7, 8, 9, 10 and 11; through which points, Lines drawn from the Centre R, ſhall be the true *Fore-noon Hours.*

For the Afternoon hours, the ſhorter Line 12, 6. on your *Dial-plain*, muſt be divided from the Line A C in the *Preparative Scheme*, as the longer Line 12, 6 was before divided; by taking the leaſt diſtance from A or 9, 3 to the line M C, and ſetting it from 12 to 3, or from 6 to 3. —— Alſo the leaſt diſtance from 2, 10, to M C, in the *Preparative Scheme*, will reach from 12 to 2, and from 6 to 4.---- Likewiſe the leaſt diſtance taken from 1, 11, to the Line M C, in the *Preparative Scheme*, will reach from 12 to 1, and from 6 to 5. So is the ſhorter Line 12 6, on the Dial-Plain, divided into ſix unequal parts in the Points 1, 2, 3, 4, 5. Through which points, and the Centre R, right Lines being drawn, they ſhall be the true Afternoon Hour-lines upon the Plain. And ſo is your Dial finiſhed.

If you would inſert the Halfs and the Quarters of Hours into your Plain, you may eaſily do it, if from the *Preparative Scheme* you take the neareſt diſtance from the Half and Quarter points in the Line A C, and transfer them to the Lines 12, 6, and 12, 6, in the *Dial-Plain.*

Section. II.

How to deſcribe Hour-lines upon the Horizontal Full South, North, Eaſt and Weſt Erect or Reclining Plains.

IN theſe kind of Plains, which directly behold the Four Cardinal North, South, Eaſt and Weſt points, the Latitude of the place, and Reclination of the Plain being known, there is nothing required, but to know the *Elevation, or height of the Pole above the Plain*, which, how to find, is ſufficiently taught in the *Fourth* and *Fifth Sections* of the *Fourth Part* of this *Book*: And therefore I ſhall not here repeat the ſame again, but refer you to thoſe forementioned Fourth and Fifth *Sections* of the *Fourth Part* hereof. Wherefore, to draw Hours upon any of theſe *Erect*, *Direct*, or *Direct Reclining Plains*, when the height of the Pole or Stile above the Plain is found, you have no more to do; but,

Firſt, Draw a right line A B for the Hour-line of Six, and another at right Angles thereto, for the Hour-line of 12, as the Line ⊙ X.

Secondly, With the Radius of your Line of Chords 60 d. upon ⊙ as a Centre, deſcribe the Semicircle A X B. And the height of the Pole above the Plain being known, (as for an *Horizontal Dial* for *London*, where the Pole is elevated 51 deg. 30 min.) Take 51 deg. 30 min. from your Chord, and ſet them upon the Semicircle from X to F, and from X to I, and through the points F and I, draw the Lines 6 F and 6 I, parallel to ⊙ X, and draw the Lines X 6 and X 6 on either ſide of the Meridian.

Thirdly, (Having recourſe to your former *Preparative Scheme*) take in your Compaſſes the length of the Line X 6, and ſet it upon the *Preparative Scheme* from B to *c*, and laying a Ruler from A to *c*, draw the pricked Line C △.

Fourthly,

Fourthly, In the *Preparative Scheme* from the point A or 9, 3, take the neareſt diſtance to the pricked Line Δ C, and ſet it upon the Lines X 6, and X 6, from X to 3, and from X to 9. Alſo from the point 2, 10, in the Line A C of the *Preparative Scheme*, take the neareſt diſtance to the pricked Line Δ D, and that diſtance ſet upon the Lines X 6, and X 6, from X to 10 and 2, and from 6 to 8, and from 6 to 4. — Likewiſe, take the neareſt diſtance from the point 1, 11, in the Line A C of the *Preparative Scheme*, to the pricked line Δ C, which diſtance will reach from X to 11, and from X to 1, and alſo from 6 to 5, and from 6 to 7. So are the two Lines X 6 and X 6 divided each of them into ſix unequal parts, the one in the points 1, 2, 3, 4, and 5, and the other in the points 11, 10, 9, 8 and 7. Through which points, right Lines drawn from the Centre ⊙, they ſhall be the true Hour-lines proper for an *Horizontal Dial*, for the Latitude of *London* 51 deg. 32 min.

For the Stile of this Dial, a Line drawn from the Centre ⊙, through either of the points F and I, ſhall repreſent the *Axis of the World*, or *Stile of the Dial.*

For a Vertical or Erect South Dial for the ſame Latitude 51 *deg.* 32 *min.*

The height of the Pole above a *South Plain* in the Latitude of 51 deg. 32 min. is 38 deg. 28 min. the Complement of the Latitude. Wherefore,

Firſt, Take 38 deg. 28 min. from your Scale of Chords, and ſet them from X to G, and from X to H, and draw the Lines X M and X D, parallel to ⊙ X.

Secondly, Take the length of the Line X M and X D, and apply it to your *Preparative Scheme*, ſetting it from B to *d*, and laying a Ruler from C to *d*, draw another pricked Line C Æ.

Thirdly, The neareſt diſtances taken from the points A, 2, 10, and 1, 11, in the Line A C of the *Preparative Scheme*,

will (being transferred from thence to the *Dial-plain*) divide the Lines X M and X D, each of them into ſix unequal parts, through which diviſions, and the Centre ⊙, Lines being drawn, they ſhall be the true Hour-lines of an *Erect South Dial* in the Latitude of *London*.

A Line drawn from ⊙ (the Centre of the Dial) through the points H or G, ſhall repreſent the *Axis of the World*, and be the *Stile* of this *Dial*.

For a Direct North Reclining Plain.

Let our Example be of a *Direct North Plain Reclining* from the *Zenith* 25 deg. and ſuch a *Dial* is deſcribed in the 17*th*. Chapter of the *Firſt Part*, and the height of the *Pole* or *Stile* above the *Plain*, was there found to be 63 d. 28 min. And ſo it will be found to be by the Rule delivered in the *Fifth Section* of the *Fourth Part* of this Book.

Firſt, The height of the Stile being found to be 63 d. 28 min. take 63 deg. 28 min. from the Scale of Chords, and ſet them from X to E, and from X to K, and draw the Lines E C, anp R D, parallel to the Meridian ⊙ X. Alſo, draw the Lines X C and X D.

Secondly, Take the length of the Line X C or X D, and ſet it upon the *Preparative Scheme* from B to *e*, and draw a third pricked Line as *e* C.

Thirdly, The neareſt diſtances taken from the points A, 2, 10, and 1, 11, in the Line A C, ſhall (being ſet upon the Lines X C and X D) divide them each into Six unequal parts; through which, and the Centre ⊙, right lines being drawn, they ſhall be the true Hour-lines of a *North Direct Plain Reclining* 25 deg. the Latitude of *London*.

The Stile muſt be drawn from the Centre ⊙, through the point E or K.

For

For Direct Eaſt or Weſt Plains, whether Erect or Reclining.

For *Erect Direct Plains*, where the Hour-lines are parallel one to another, the Stile or Pole having no Elevation, the beſt way to make them, is, as is directed in the *Sixth Chapter* of the *Firſt Part*. And therefore in this place, nothing more need be ſaid concerning them. But,

For Eaſt and Weſt Recliners.

The beſt way to deal with theſe kind of Plains, is to refer them to a *new Latitude*, and to a *new Delineation* in that *new Latitude*, both which are eaſily attained by this following *GENERAL RULE.*

1. *The New Latitude, is always the Complement of the Old Latitude.*
2. *The New Declination in that New Latitude is the Complement of the Reclination.*

So that if a Direct *Eaſt Plain*, in the Latitude of *London* 51 deg. 32 min. ſhould Recline 40 deg. and you would find the New Latitude and New Declination;

Firſt, The Complement of the *Old Latitude* 51 deg. 32 min. is 38 deg. 28 min. And that muſt be the *New Latitude.*

Secondly, The Reclination being 40 deg. The Complement thereof is 50 deg. And that is the *New Declination.*

So that if (by the directions of the *Firſt Section* hereof) you make an *Erect Dial* to decline 50 deg. in the Latitude of 38 deg. 28 min. that *Dial* ſhall ſerve for an *Eaſt* or *Weſt Dial*, *Reclining* 40 d. in the Latitude of 51 d. 32 m.

Thirdly, Although this *Declining Plain* be truly made, yet

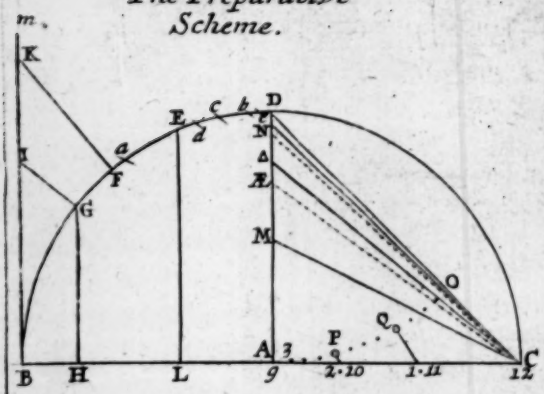
yet the placing of it upon the *Dial-Plain*, differeth from *Erect Plains*: For, in all Erect Declining Plains, the Hour-line of 12 is always perpendicular to the *Horizontal Line of the Plain*. So in all *Eaſt* and *Weſt Reclining Plains*, the Hour-line of 12 muſt lie parallel to the Horizontal Line of the Plain. As you may ſee in the *Figure* Chap. 10, of *Part* the *Firſt*.

It may here be expected, that I ſhould ſay ſomething concerning *Declining Reclining Plains*, which this *Geometrical* way will very well perform, by referring them to a *New Latitude*, and a *New Declination*, where they will become *Erect Declining Plains*; but for that the performance thereof, this way, would require many Schemes, and that there are *Three* ways in this Book, already taught, how to effect the ſame by other means, I thought good to omit them in this place; and to give Examples in *Erect Direct*, in *Direct Reclining*, and in *Erect Declining Plains*, (as being of all others the moſt uſeful.) And ſo I ſhall conclude this *Second Geometrical Way* of *Dialling*.

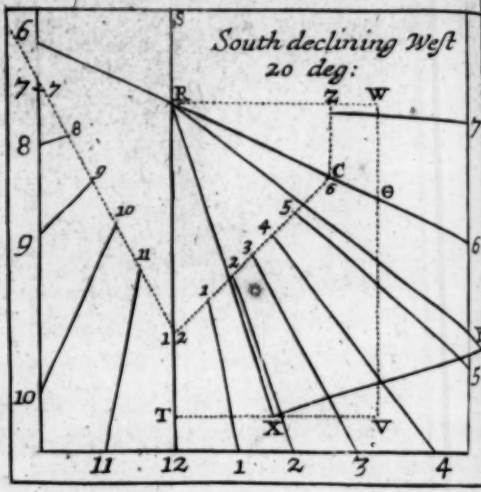
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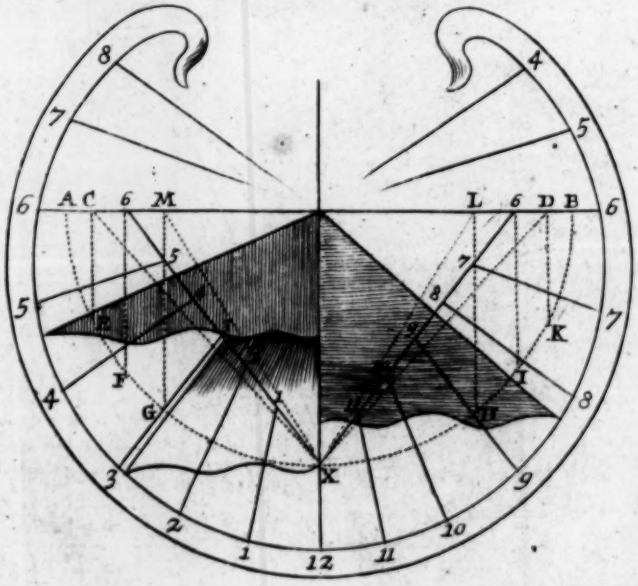


The Preparative Scheme.



South declining West 20 deg:





This belongs to page 127.

The *ART* of

DIALLING,

INSTRUMENTALLY

PERFORMED:

By a Plain, Cheap, and Portable Inſtrument, accommodated with Lines neceſſary for that purpoſe.

PART. III.

CHAP. I.

A Deſcription of the Inſtrument.

THE Inſtrument may moſt conveniently be made upon a thin Plate of Braſs (the thinner the better.) Let it be made in the form of a Right-angled Triangle, one of the ſides containing the right Angle being in the Figure marked with A B, let it be divided as a Line of Natural Sines, and the other ſide noted with A C, let be divided as a line of Natural Tangents, of ſuch a length that it may contain 75 degrees at the leaſt of the ſame Radius with the Line of Sines. Let both the Sines and Tangents be numbered from A, by 10, 20, 30, *&c.* according to the uſual manner, the Sines to 90 deg. and the Tangents to 75 or upwards —— The diviſions of both theſe lines muſt be graduated

graduated close to the outer edges of the Brass as Protractors are usually divided, and the Metal not exceeding that thickness. —— On the third edge B C, is graduated a line of double Tangents of any Radius, such as the line is capable to receive 45 deg. on either side from the middle thereof, from D to E 45 deg. and from D to F as many; which Tangents are to be numbred not into degrees of a Circle, but into degrees of Time, allowing 15 deg. to 1 hour, 30 for 2 hours, and 45 for 3 hours, and the other intermediate parts for Halfs and Quarters, and in larger Instruments into smaller parts —— This I call the Scale of hours, and must be numbred as in the Figure XII, standing at one end, and VI at the other end thereof, IX and III in the middle, and the rest in order, as in the Figure ----- And it were not amiss, if the Tangent line A C were marked at the degrees of Time, as well as into degrees of the Circle, which will be useful in the description of East, West, and Æquinoctial Dials both direct and declining.

In some convenient place of the Plate you may have one, two or three Lines of Chords to several Radius's, which will perform the work of the First Part of this Book, and will also be serviceable in this.

Also it would be necessary that the other side of the Plate were graduated for the Lines of Sines and Tangents, in all respects, as the fore-side: But for the line of hours it were not amiss to have two or three of them of several lengths, as in practice you may find occasion for, though one will do all. And this may easily and commodiously be done if the middle of the Plate be cut out, and then on all the inner edges of the Plate, you may have several Lines of hours, and between them Chords also. A Quadrant also may be projected upon this Instrument, and then it will be serviceable to take a declination of a Plain; for by it you may find the Azimuth. The Instrument thus fitted will be very portable, and very exact and easie in practice. For these last mentioned parts, I leave them to the discretion of the Artificer, or the

the will of the Owner, the firſt three lines being ſufficient to perform all the following works. This Inſtrument thus made, I call (in reſpect of the Figure of it) an *Horological Trigon.* The uſes whereof are exhibited in the following Chapters.

CHAP. II.

How to draw the Hour-lines upon all ſorts of Direct Plains, by help of the Horological Trigon.

Dials may be delineated upon all ſorts of Plain Superficies, by help of this *TRIGONAL INSTRUMENT.* And that I may retain herein the like Method as I have obſerved in the Three foregoing *Treatiſes*, I ſhall begin with the *Direct Plains* firſt, and from them proceed to the *Oblique.* And in my proſecution hereof, I ſhall more lightly paſs over ſuch things as I have in the firſt Part more particularly handled, ſo by this means the ſubſequent Treatiſe will be the more brief, and the leſs cumbred with Precepts: And I ſhall begin with ſuch Plains as are *Direct*, whether *Erect* or *Reclining.*

Section I.

How to draw the Hour-lines upon a Vertical *or* Horizontal *Plain, as alſo upon any direct* North *or* South Plain *in any Latitude, whether Erect or Reclining.*

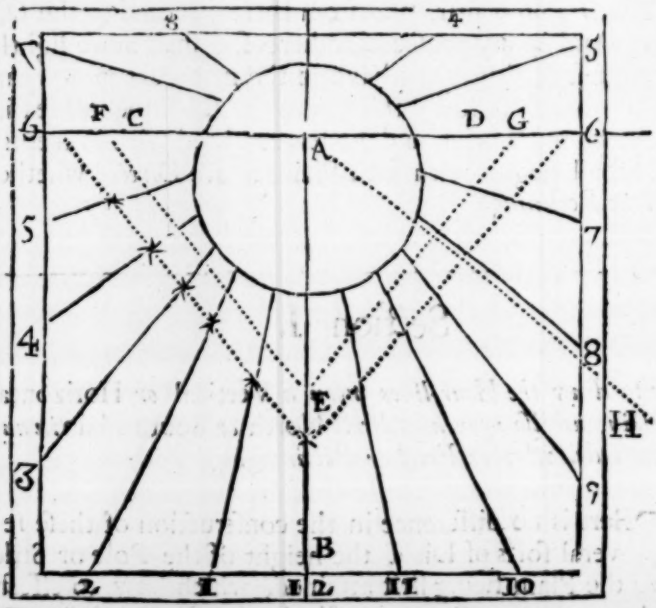
THere is no difference in the conſtruction of theſe ſeveral ſorts of Dials, the height of the Pole or Stile above the Plain being firſt attained, which how to effect, is at large taught Geometrically in the Firſt and Second

Part, Chap. 3. and in the Fourth Part, Sect. 1. and therefore in this place will be needleſs to recite. Wherefore let us take one Example for all, *viz.*

To draw the Hour-lines on a Vertical *or* Horizontal *Plain, in the Latitude* 51 *deg.* 32 *min.*

Firſt, Upon your Plain (or upon a Sheet of Paper) draw a right line A B for the Meridian (or hour-line of 12,) and aſſigning any point therein (as A) for the Centre of your Dial, through it draw the line C A D at right Angles for the Hour-line of 6.

Secondly, Lay the Centre of your Trigon, to the Centre of your Dial, ſo that the Tangent-line thereof may lie upon the Line of 12, and the Line of Sines upon the Line of Six.



Thirdly, With a Needle (or protracting Pin) make a Mark

Mark upon the Meridian Line, againſt (the Radius or) 45 deg. as the point E. And upon the line of 6 make another mark, againſt the Sine of your Stiles height (in this Example againſt 51 deg. 32 min.) as at F, and draw the line E F. Do the like on the other ſide of the Meridian line, by making A G equal to A F, and draw the Line E G.

Fourthly, Divide the lines E F and E G (each of them) into two equal parts, in the points 9 and 3, and from the Centre of your Dial through theſe points 9 and 3, draw two right lines, which ſhall be the Hour-lines of 9 and 3 of the Clock.

Fifthly, For the drawing of the reſt of the hours, lay the Line of Hours upon your Trigon to your Plain, in ſuch manner, that the point or end thereof noted with 6, and the other end or point thereof noted with 12, may juſtly touch the Hour-lines of 12 and 6 upon your Dial-plain, and move the Line of hours between the two Hour-lines of 12 and 6 backwards or forwards (as occaſion ſhall require) till the middle of the Line of Hours, noted with the hours 9 and 3, reſt juſt upon the Hour-line of 9 or 3 upon your Plain ---- Your Line of Hours lying in this poſition with your protracting Pin (or Needle) make marks upon your Plain, againſt every Hour, half and Quarter, as the points *** *&c.* ------- And from the Centre of your Dial, (through theſe reſpective points) draw right Lines and they ſhall be the true Hour-lines proper to your Plain.

Do the like on the other ſide of the Meridian for the Afternoon hours, and your Hour-lines are all drawn, except thoſe before 6 in the morning, and after 6 at night, which muſt be drawn through the Centre, according to the direction given in Part I. Chap. 3.

It may ſeem at firſt ſomething difficult to enter the line of Hours upon your *Trigon*, between the Hour-lines of 12 and 6, and ſo as the point 9 or 3 may reſt upon the Hour-line of 9 or 3 alſo; but know there is no difficulty at all, but wonderful eaſie, and ſo expeditious, that the *Trigon* is prepared to prick down all the

Hours, halfs and quarters, as ſoon as you could with your Compaſſes, take one of them out of a Scale, and will give you the hour points upon the Plain more exact than you can ſet them well off with the Compaſſes ---- And farther Note, that your *Trigon* lying in this poſition, the Line of hours on your *Trigon*, will always lie parallel to the lines E F, and E G, if there be no former errour.

Laſtly, For the height of the Stile above the Plain (it is in this Example, equal to the Latitude of the place 51 deg. 32 min.) this you may ſet off by a Line of Chords (as hath been often ſhewed before) but by the *Trigon* thus ---- Lay the Centre of your *Trigon* upon the point E, the line of Sines lying upon the Meridian (or 12 a Clock) line, then againſt the Tangent of 51 deg. 32 min. make a mark as H, and draw the line A H for the Stile, ſo is your Dial finiſhed.

And according to this precept may the Hour-lines upon all *North* and *South Direct Plains* be drawn, without any farther trouble, and ſo for ſuch plains, let this one precept ſuffice.

Section II.

How to draw the Hour-lines upon the Direct Eaſt Weſt *upright and* Æquinoctial Reclining *Plains, by help of the* Trigon.

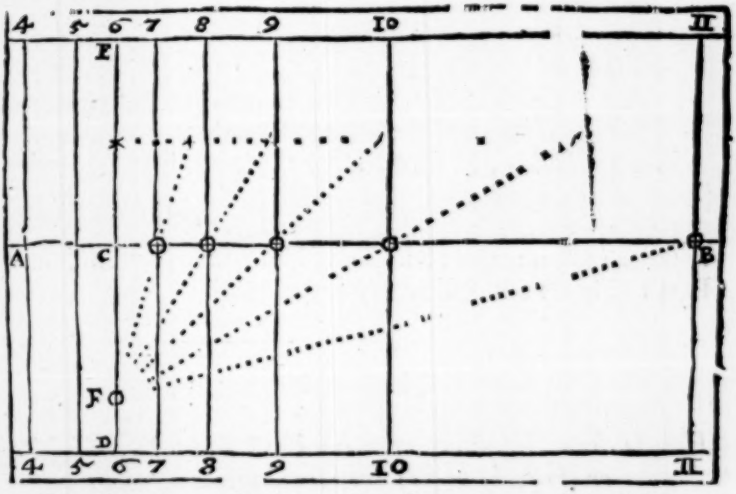
OUr Example ſhall be of an Eaſt Erect Direct Plain in the Latitude of 51 deg. 32 min. Wherefore,

Firſt, Draw (by the directions in Part I. Chapter 6. a Right-Line A B for the Æquinoctial, and in any point thereof, as at C, draw a right line D C E (at right Angles thereunto) for the Hour-line of 6.

Secondly, Aſſign any point of the Hour-line of 6, (proportional to the bigneſs of your Plain) as F for the height of your perpendicular Stile or Gnomon.

Thirdly,

Thirdly, Lay the *Trigon* to your Plain, ſo that the Line of Sines may lie juſt upon the Hour-line of 6, and the end thereof at 90 deg. upon the point F ----- The *Trigon* lying in this poſition, with your Needle or protracting Pin, make marks upon your Plain, by the ſide of the Tangent line upon your *Trigon*, at every hour, half and quarter, at the marks *** *&c.* (for the Tangent line upon the *Trigon*, is divided into hours and parts of time, as well as into degrees and minutes.)



Fourthly, Lay a Ruler to F, and every one of theſe hours, halfs and quarters, and where the Ruler croſſeth the Æquinoctial Line of the Plain A B, as at the points ⊙ ⊙ ⊙, *&c.* through thoſe points draw right lines parallel to the Hour-line of 6, and they ſhall be the true Hours proper for your Plain.

For the hours before 6 in the morning on the *Eaſt Dial*, and after 6 at night on the *Weſt Dial*, the ſame diſtances ſet backwards upon the Æquinoctial-line, will give you thoſe points as is directed in Part I. Chap. 6.

Note,

Note, If you make your Dial anſwerable to the bigneſs of your *Trigon*, much of the labour in making of this Dial will be ſaved: For, when you have drawn A B the Æquinoctial, and croſſed it at right Angles, with the Line C D E for the Hour-line of *6* ------ Lay the Centre of the *Trigon* upon the point D, and the Tangent line of the *Trigon* upon the Æquinoctial Line of the Plain, and ſo making marks at every hour, half, and quarter, lines drawn through thoſe points parallel to the Hour-line of *6*, ſhall be the true hours proper for the Plain---- And here note alſo, that the Line A B firſt drawn, muſt make an Angle with the Horizontal Plain, equal to the Complement of the Latitude of the place, for which the Dial is made.

What is ſaid of the Eaſt Plain, the ſame is to be underſtood of the Weſt, as in Part I. Chap *6*. and the ſame of the Æquinoctial Plain alſo, only the *6* a Clock Hour-line in theſe Plains, is the 12 a Clock Hour-line in thoſe, as in Part I. Chap. 12 is ſufficiently explained.

CHAP. III.

How to draw Hour-lines upon any Erect Plain, Declining Eaſt or Weſt, by help of the Horological Trigon.

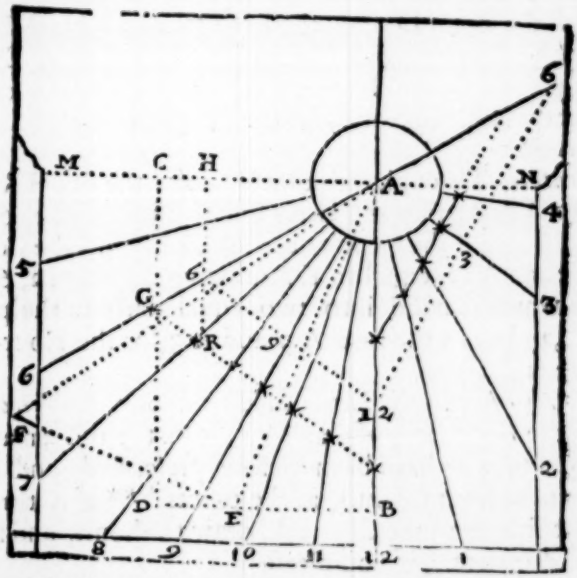
THeſe are the Dials, which (of all others) are moſt in uſe, and therefore will require the more care in the practice of the making of them; and that I may remove all difficulties that may ariſe in the making of them at any time, I ſhall be the more large in this particular, for (indeed) upon the making of theſe Dials in all Latitudes, doth depend the making of all other Oblique Dials, whether Reclining or Inclining, as hereafter ſhall be taught.

SECT.

Section I.

How to deſcribe the Hour-lines upon an Erect *or* Upright Plain, Declining *from the* South Eaſtward 30 *deg. in the* Latitude of 51 *deg.* 30 *min.*

Firſt, Draw a perpendicular or down-right line A 12 B, for the Meridian and Hour-line of 12, and making choice of ſome convenient point therein, as A, for the Centre of your Dial, draw through that point an Horizontal Line M A N.



Secondly, Apply the Centre of the *Trigon*, to the Centre of the Dial at A, ſo that the Line of Sines may lie upon the Line M A, and the Line of Tangents upon the line A B: And againſt the Tangent of the Latitude of the place 51 deg. 32 min. make a mark at B, and alſo at the Co-Sine of

of the Latitude 51 deg. 32 min. make another mark at H.

Thirdly, Remove the *Trigon*, laying the Centre thereof to B, and the Line of Tangents upon B A, and againſt the Sine of the Declination 30 deg. make a mark, as E, and draw the Line A E for the Subſtilar line of the Dial.

Fourthly, Upon the point E, erect a perpendicular, and laying the Centre of the *Trigon* upon E, and the Line of Sines upon the perpendicular, make a mark againſt the Co-Sine of the Plains Declination 60 deg. as at F, and draw the Line A F for the Stile.

Fifthly, Laying the Centre of the *Trigon* to B, and the line of Sines upon A B, make a mark againſt the Co-Tangent of the Latitude of the place 38 deg. 28 min. as at D, and through the point D draw the line D C parallel to A B.

Sixthly, Take in your Compaſſes the diſtance B E, and ſet it upon the line C D from C to G, and draw the Line A G for the Hour-line of 6, quite through the Centre, as the line 6 A 6.

Seventhly, Through the point H, draw the line H R, parallel to A B, cutting the Hour-line of 6 in the point 6, and make A 6 above the Centre, equal to A 6 below the Centre, and the line A 12, equal to E F, drawing the lines 12, 6, and 12, 6, which divide into two equal parts in the points 9 and 3, and draw the lines A 9 and A 3, for the Hour-lines of Nine and Three.

Eighthly, Apply the Line of Hours upon your *Trigon*, between the Hour-lines of 6 and 12, ſo that 9 and 3 may reſt upon 9 and 3 as hath been before preſcribed, and make marks at the ſeveral hours, as the points *** *&c.* through which points, and the Centre A, draw the hours, and ſo the halfs and quarters, if you pleaſe.

For the line of 5 in the morning, it is drawn by extending the Hour-line of 5 at night through the Centre. And in the making of this Dial, you have made four Dials as is declared, and largly inſiſted upon, Part I. Chap. 8. and therefore no more need be ſaid of it in this place.

Theſe

Theſe Precepts here delivered, are ſufficient for the making of Upright Declining Dials in any Latitude, but moſt conveniently in theſe middle Latitudes, under the temperate Zones; in the Torrid and Frigid Zones there may fall out ſome Inconveniencies, for when the Latitude is either very great or very ſmall, ſuch as the lines on the *Trigon* are not capable to receive, there are other means to remedy thoſe Inconveniencies, which ſhall be cleared by the two following Propoſitions, one whereof, ſhall ſhew how to effect the work of this Chapter, when the Latitude is very ſmall, the other when it is very great.

Section II.

PROP.

To draw an Upright Declining Dial in ſuch a Latitude, where the Pole hath but ſmall Elevation.

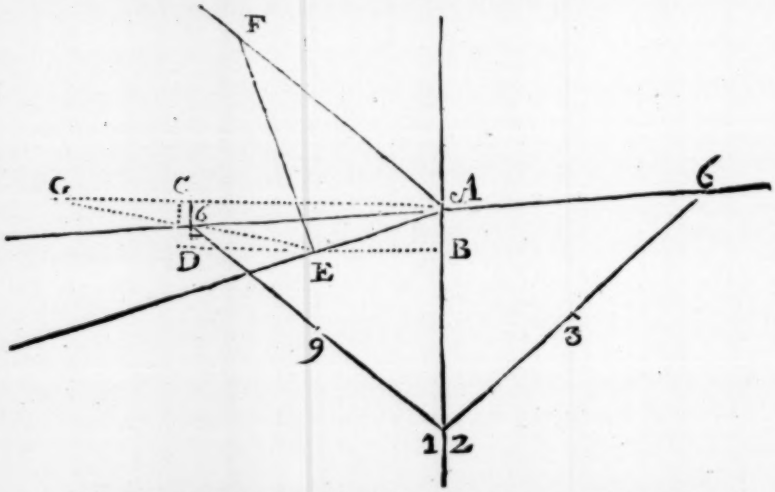
Let the Example be of an Upright South Plain Declining Eaſtward 30 deg. in the Latitude of 10 deg.

Firſt, Draw a line A B 12, for the Meridian and Hour-line of 12, and make choice of a point therein for a Centre, as A, through which draw a line perpendicular thereto for the Horizontal line of the Plain, as the Line G C A.

Secondly, Lay the Centre of the *Trigon* to the Centre of the Dial, and the Tangent-line thereof upon the Line A B 12. And againſt 90 deg. or the Radius of the line of Sines, make a mark as C, and alſo againſt 80 deg. thereof, which is the Complement of the Latitude of the place, as at H. Likewiſe againſt the Tangent of the Latitude 10 deg. make a

mark, as at B, and draw the Lines B D parallel to to the Horizontal line G C A, and the line C D parallel to the Meridian Line A B.

Thirdly, Lay the Centre of the *Trigon* upon B, and the Line of Sines upon B D, and make a mark againſt the Sine of the Plains Declination 30 deg. as E, and draw the Line A E for the Subſtilar Line of the Dial; then take the diſtance B E, and ſet it upon the Horizontal line of the Plain from C to G, and draw the line E G, cutting the line C D in K, ſo ſhall A K be the Hour-line of *6*.



Fourthly, Upon the point E, erect the perpendicular E F and laying the Centre of the *Trigon* upon E, and the Line of Sines upon E F, make a mark againſt the Sine of the Complement of the Plains declination 60 deg. at the point F, and draw the Line A F for the Stile.

Fifthly, Through the point H, draw the line H M, parallel to the line A B, cutting the Hour-line of *6* in the point *6*. then taking the diſtance E F in your Compaſſes, make the line A 12 equal thereto, and the line A *6* above the Centre equal to A *6* below the Centre, and draw the lines *6*, 12. and

and 6,12. which divide into two equal parts in 9 and 3, and for the other hours apply the line of hours of the *Trigon*, as is before directed, and finiſh the Dial, according to former Precepts.

PROP. II.

How to draw an Upright Declining Dial in ſuch a Latitude where the Pole hath great Elevation.

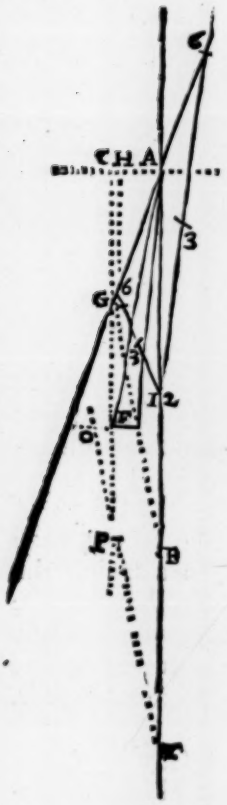
Let the Example be of a South Plain declining Eaſtward 30 deg. in the Latitude of 80 deg.

Firſt, Draw a Line A R for the Meridian and Hour-line of 12, and through the Centre A draw the Horizontal Line C A perpendicular thereunto.

Secondly, Lay the Centre of the *Trigon* to the Centre of the Dial, ſo that the Line of Sines may be upon the Line A B, and the Line of Tangents upon A C, then againſt the Radius or Sine of 90 deg. make the mark B, and againſt the Co-Sine of the Plains Declination 30 deg. make the mark 12; alſo, againſt the Co-Tangent of the Latitude make the mark or point C, and draw the line C D parallel to A B, and the line B D parallel to C A.

Thirdly, Lay the Centre of the *Trigon* to C, and the line of Sines upon C B, and againſt the Sine of the Plains declination 30 deg. make the point G, and make B R equal to C G, then draw the Line R G, cutting the line B D in E, ſo ſhall A E being drawn be the Subſtile, and A G the Hour-line of *6*.

Fourthly, Take in your Compaſſes the diſtance A 12, and ſet the ſame from G to P, and from R to T (thoſe Lines being extended) then draw the line T P, cutting the Line D B extended in O, and upon E erect the perpendicular E F equal to E O, and draw A F for the Stile of the Dial.



Fifthly, Lay the Centre of the *Trigon* to the Centre of the Dial, and the line of Sines upon A C, and againſt the Co-Sine of the Latitude 10 deg. make the mark H, and draw the line H M parallel to A B, cutting the Hour-line of *6* in *6*, make A *6* above, equal to A *6* below the Centre, and draw the lines 12, *6*. and 12,*6*--- Divide them into two equal parts at the points 9 and 3, and applying the line of hours on your *Trigon* to them, you may prick down the hours, halfs and quarters, as hath been already preſcribed.

Thus have you the manner of pricking down the Hour-lines upon *Upright Declining Plains* in any Latitude, and that in all caſes. It reſteth now that we ſay ſomething of *Declining Reclining Plains*, and the beſt way for them in this caſe, is to refer them to a new Latitude, and a new Declination, wherein they would become Upright Declining Plains. And how to find this *New Latitude*, and and *New Declination*, ſhall be the work of the next Chapter.

CHAP.

CHAP. IV.

The Declination *and* Reclination *of a Plain in a known* Latitude *being given, to find in what* Latitude *the ſaid* Reclining Declining Plain *ſhall be an* Upright Plain, *and alſo, what* Declination *the ſame ſhall have in that* New Latitude, *and how much the* Meridian aſcends above, *or* deſcends below *the* Horizontal Line of the Plain, *and which ways.*

SUppoſe a Plain in the Latitude of *London*, 51 deg. 32 m. ſhould decline Northerly 60 deg. and Recline alſo 54 deg. (ſuch a Plain is the laſt Example of North Reclining Declining Plains, in the Firſt Part of this Book.) And it were required to find,

1. In what Latitude that would be an Upright Plain. And,
2. What Declination it ſhall have in that new Latitude. And,
3. How much the Meridian is elevated or depreſſed above or below the Horizontal Line.

Section I.

To find the New Latitude.

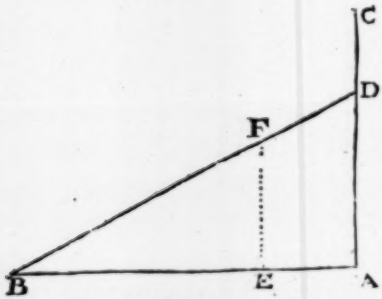
Firſt, Draw a Right-line B A, and at the end thereof A, raiſe a perpendicular A C.

Secondly, Lay the Centre of the *Trigon* to the point A, ſo that the Line of Sines may lie upon the Line A C, and the Line of Tangents upon A B. Then,

Thirdly, Make a mark againſt the Co-Sine of the Plains Declination 30 deg. as D, and another mark againſt the Radius,

dius or Tangent of 45 as at B —— Then turning the Centre of the *Trigon* to B, lay the Tangent line upon B A, and make a mark againſt the Co-tangent of the Plains Reclination 36 deg. as at E.

Fourthly, Draw the line D B, and apply the Centre of the *Trigon* to E, ſo that the Line of Sines may lie upon E A: Then will the line D B lie under the Tangent of 19 deg. 58 min. This Tangent of 19 deg. 58 min. you muſt compare with the Complement of your old Latitude 38 deg. 28 min. in North Reclining Plains (as in this Example) and take their difference, which is 18 deg. 30 min. And that is the new Latitude.



And here note, that if the Tangent E F before found prove to be equal to the Complement of your old Latitude, then will your Plain, be a Polar Declining Plain. But again,

In South Reclining Plains, you muſt compare the Tangent E F with your Latitude, and find their difference, the Complement of which difference ſhall be your new Latitude.

And *Note* farther, That (in South Recliners,)

If the Tangent E F be leſs than your old Latitude, the contrary Pole is elevated; and if it be equal to your Old Latitude, then it is an Æquinoctial Plain.

Section

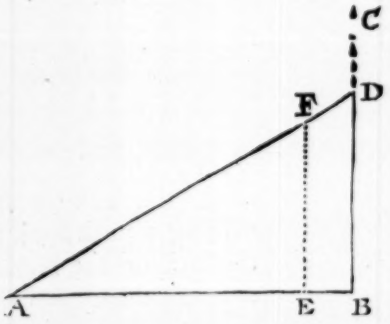
Section II.

To find the New Declinations.

FIrſt, draw a Right Line A B, and upon the point B erect the perpendicular B C.

Secondly, Lay the Centre of the *Trigon* to the Point B, ſo that the Line of Sines may lie upon B C, and the Line of Tangents upon A B, then make a mark againſt the Tangent of 45 deg. (or the Radius) as at A, and another againſt the Co-Sine of the Reclination 36 deg. as at D, and draw the Line A D.

Thirdly, Lay the Centre of the *Trigon* upon A, and the Line of Sines upon the line A B, and make a mark againſt the Sine of the Old Declination (60 deg.) as at E.



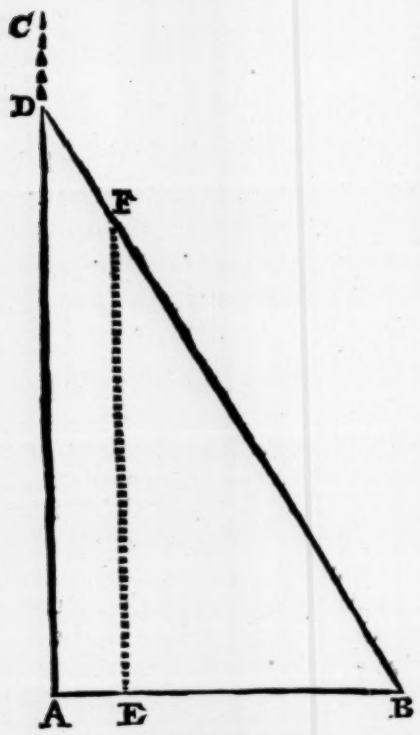
Fourthly, Lay the Centre of the *Trigon* to E, and the Tangent line upon A E, ſo ſhall the line A D lie juſt under the Sine of 30 d. 38 min. in the *Trigon*, at the point F, and this 30 deg. 38 min. is the new Declination.

And here note, that this new Declination thus found, is always to the ſame Coaſt, Eaſtward or Weſtward with the old, but always leſs in quantity.

Section III.

To find the Angle that the Meridian makes with the Horizontal Line of the Plain.

Firſt, Draw the two Lines A B, and A C, making a right-angle at A.



Secondly, Lay the Centre of the *Trigon* to A, and the Tangent Line upon A C, and make a mark againſt the Tangent of the old Declination 60 deg. at D, and another againſt the Sine of 90 deg. and draw the Line D.

Thirdly, Lay the Centre of the *Trigon* upon B, and the Sines upon the Line B A, making a mark againſt the Sine of the Reclination 54 deg. at E.

Fourthly, Lay the Centre of the *Trigon* to E, and the Sines upon E B, then will the Line B D, lie juſt under the Tangent of 54 deg. 29 min. which is the Complement of 35 d. 31 m. and an Angle of that quantity doth the Meridian make with the Horizon.

By theſe Three Sections of this Chapter, you have reduced

reduced your North Plain, in the Latitude of 51 deg. 32 min.

Reclining 54 deg. 00 min. And
Declining 60 deg. 00. min.

To an Upright Declining Plain in another Latitude, *viz.* To

	deg.	min.
North Plain Declining Weſt	30	38
In the Latitude of	18	30

So that if by the Precepts delivered in the Third Chapter of this Part, and by the Second Section thereof, becauſe the Latitude is but ſmall, you ſhall have a true Dial for ſuch a Plain, as declines and reclines the quantities above mentioned in the Latitude of 51 deg. 32 min. Which Dial being truly drawn, and applied to the Reclining Plain, the Meridian making ſuch an Angle as was found by the Third Section of this Chapter, *viz.* 35 deg. 31 min. and placed towards the right Coaſt (as ſhall be ſhewed in the next Chapter) your work is finiſhed, the Precepts here delivered being general.

CHAP. V.

Sewing whether the Meridian Line of the Plain aſcends above, or deſcends below the Horizontal Line of the Plain, and towards what Coaſt.

THe Third Section of the laſt Chapter gave you the quantity of this Angle, now for the poſition of the Meridian line, obſerve theſe general Rules following, *viz.*

In North Incliners. South Recliners.

- Leſs than Æquinoctial, the Meridian muſt be drawn.
  - above — That end of the Horizontal Line, which lies contrary to the coaſt of the Plains Declination.
  - below
- More than Æquinoctial, the Meridian muſt be drawn.
  - below — That end of the Horizontal Line, which lies the ſame way with the coaſt of the Plains Declination.
  - above

In North Recliners. South Incliners.

- Leſs than a Polar the Meridian muſt be drawn.
  - above — That end of the Horizontal Line that looks the ſame way with the Coaſt of the Plains Declination ---- And this Meridian thus drawn in Narth Recliners, repreſents 12 at midnight.
  - below
- Equal to a Polar, the Meridian muſt be drawn below the Horizontal Line at that end which is contrary to the Coaſt of Declination, and the Six of Clock Hour-Line is always the Subſtile.
- More than a Polar the Meridian muſt be drawn.
  - below — And from that end of the Horizontal Line, which lies contrary to the Coaſt of the Plains Declination ---- And in South Incliners it is only ſerviceable to help to draw the reſt of the Dial.
  - above

Your Dial being drawn by the Precepts delivered in the third Chapter of this Part, according to its new Latitude and new Declination, and the ſituation of the Meridian Line from the Horizontal line, diſcovered by this Chapter, you may now proceed to

The Placing of the Dial upon the Plain.

Which to perform, having by the directions given, drawn an Horizontal line upon your Plain, ſet off ſo many degrees (by help of your Line of Chords) as the diſtance of the Meridian from the Horizon is found to be, and to the ſame Coaſt, and there draw the Meridian Line. Having ſo done, apply your Paper-draught to your Plain, and lay the Meridian Line thereof upon (or parallel to) the Meridian Line upon your Plain, and herein be careful that the Stile of your Paper-draught (or rather a true pattern thereof cut out in Paſt-board or Paper) being placed upon the Subſtilar do directly behold or point towards the Elevated pole; which conſideration being had, you may eaſily tranſfer the reſt of the Hour-lines from your Paper to your Plain, and put no more thereon than are neceſſary.

CHAP. VI.

How to deal with Eaſt and Weſt Reclining and Inclining Plains.

THeſe alſo muſt be referred to a new Latitude, and new declination, which are eaſily attained; the new Latitude being always the Complement of your own Latitude, and the new Declination in that Latitude, is the Complement of their Reclination. Theſe being known, you may deſcribe the Dial according to the Rules of the Third Chapter.

The Meridian Line in all theſe Dials, is the ſame with the Horizontal Line, and ſo hath no elevation or depreſſion.

CHAP. VII.

Of North and South Reclining and Inclining Plains.

WHen the Reclination or Inclination of any of theſe Plains is known, there is nothing elſe required before the drawing of the Dial, but the Elevation of the Pole above the Plain, which how to find is plainly taught in the Fourth and Fifth Sections of the following Part, and then the Dials are made as Vertical or Horizontal Dials for thoſe

Latitudes, and ſo no more need be ſaid of them in this place.

Concluſion.

I Shall conclude this Third Part with theſe two General and Neceſſary Rules, teaching,

1. To know which way the Subſtilar-line of any Dial muſt ſtand from the Vertical line of the ſame Plain. And,
2. How to order your work in the Southern Hemiſphere.

For the Firſt,

Upon all Plains whereon the

North Pole / South Pole

is elevated, the Subſtilar muſt lie from the

upper end / lower end

of the Vertical line towards the full

North / South

For the Second.

All the Rules, Precepts and Examples given in this Book, do ſuppoſe you to be in the Northern Hemiſphere of the World; therefore if you ſhould be in the Southern Hemiſphere, theſe Precepts will ſerve there alſo, by only changing the words North and South one into the other, as for South read North, and for North read South, and ſo Northern for Southern, and the contrary.

The

The *ART* of

DIALLING,

ARITHMETICALLY

PERFORMED,

By the *CANONS* (or *TABLES*) of Artificial *Sines* and *Tangents*.

PART IV.

The Argument.

WHeras the Two foregoing *Geometrical* Ways, and the Third *Inſtrumental* Way of delineating or making of *Sun-Dials*, may be rejected by ſome, and a more accurate performance of the ſame required by others, I thought good (to make this *Treatiſe* the more compleat, which for a *Geometrical* Way is already perfect enough) to add the *Canons*, *Analogies* or *Proportions*, by which the ſeveral *Requiſites* in all *Plains* may be *Arithmetically* attained, by help of the *Canons* or *Tables* of Artificial *Sines* and *Tangents* (then by which there can no exacter way.) Which *Tables* are already in every mans hands, and the general uſe of them no leſs common: wherefore I ſhall ſay nothing of that in this place, but proceed to the finding the forementioned *Requiſites*, as followeth. And,

Section

Section I.

Of (Vertical *or*) Horizontal *Plains.*

IN theſe Plains there is nothing required but the *Height of the Pole above the Plain*, which, in all Places, is equal to the Latitude of the Place, for which the Dial is to be made.

Section II.

Of North *and* South Erect Direct *Plains.*

IN theſe Plains alſo there is nothing required but *The height of the Pole above the Plain*, which in all places is equal to the Complement of the Latitude of the Place. Wherefore, Subſtract the Latitude of the Place, for which your Dial is to be made from 90 deg. and the Remainder is the height of the Pole above the South or North Erect Direct Plain.

	deg.	min.
From	90	00
Subſtract Latitude	51	32
There remains	38	28

Which is the height of the the Pole above a Direct North or South plain in the Latitude of 51 deg. 32 min.

Section III.

Of North *and* South Erect Declining *Plains.*

BUt in Erect Declining Plains, (beſides the Latitude of the place, and the Declination of the Plain) there are three

three things requiſite to be found, before you draw the Dial, and they are,

1. *The height of the Stile (or Pole) above the Plain.*
2. *The diſtance of the Subſtile from the Meridian.*
3. *The Plains difference of Longitude.*

Example, In the Declining plain in *Chapter* 8. whoſe Declination was 24 deg. 20 min. in the Latitude of 51 deg. 32 min.

1. *For the height of the Pole above the Plain.*

As the Radius 90 deg.	10.000000
Is to the Co-ſine of the Latitude 38 deg. 28 min.	9.793831
So is the Co-Sine of the Declination 65 d. 40 m.	9.959596
To the Sine of 34 deg. 33 min.	19.753427

Which 34 deg. 33 min. is the height of the Pole above the Plain.

2. *For the diſtance of the Subſtile from the Meridian.*

As the Sine of 90	10.000000
Is to the Sine of the plains Declination 24 deg. 20 min.	9.616059
So is the Co-tangent of the Latitude 38 d. 28 m.	9.900086
To the Tangent of 18 deg. 10 min.	19.516145

Which 18 deg. 10 min. is the diſtance of the Subſtile from the Meridian.

3. *For the Plains difference of Longitude.*

As the Co-Sine of the Latitude 38 deg. 28 m.	9.793831
Is to the Radius 90 deg.	10.000000
So is the Sine of the diſtance of the Subſtile from the Meridian 18 deg. 10 min.	19.493851
To the Sine of 30 deg. 00 min.	9.6699201

Which 30 deg 00 min. is the Plains difference of Longitude.

Section

Section IV.

Of South Direct Reclining *Plains.*

IN theſe Plains, (the Latitude of the place, and the Reclination of the Plain being given) there is only required *The Height of the Pole above the Plain*: In which there are Three Caſes, in all which you may find the Stiles height, as followeth:

1. If the Reclination of the plain be leſs than the Complement of the Latitude of the place, ſubſtract the Reclination out of the Complement of the Latitude, and the remainer will be the height of the pole or Stile above the Reclining plain. But,
2. If the Reclination of the plain be more than the Complement of the Latitude, ſubſtract the Complement of the Latitude from the Reclination, and the Remainder ſhall be the Elevation of the pole above the Plain.
3. If the Reclination be equal to the Complement of the Latitude, the pole hath no Elevation over ſuch a plain, but is an Æquinoctial plain, and muſt be made by the Rules delivered in the Twelfth Chapter of the Firſt Part of this Book.

		deg.	min.
1. Caſe	Latitude 51 deg. 32 min. Comple.	38	28
	Reclination	22	10
	Height of the pole above the Plain	16	18
2. Caſe	Reclination	62	23
	Latitude 51 deg. 32 min. Comp.	38	28
	Height of the pole above the plain	23	55

Section

Section V.

Of North Direct Reclining *Plains.*

IN theſe Plains alſo (the Latitude and Reclination being given) there is only required *The Height of the Pole above the Plain.*

To find this,

1. Add the Complement of the Latitude to the Reclination, and the ſum of them is the height of the Pole above the Reclining plain.

	deg.	min.
Latitude 51 deg. 32 min. Compl.	38	28
Reclination	27	12
Height of the Pole above the Plain.	65	40

2. But if this Sum exceed 90 deg. then ſubſtract it from 180 deg. and the remainder ſhall be the height of the Pole above the Plain.

	deg.	min.
Latitude 51 deg. 32 min. Complent	38	28
Reclination	70	42
ſum.	109	10
Which ſubſtract from	180	00
There remains	70	50

Which 70 deg. 50 min. is the height of the Pole above the Plain.

3. If the ſum of the Complement of the Latitude, and the Reclination added together do make juſt 90 deg. then that plain is a Polar Plain, and the Dial for ſuch a Plain muſt be made in all reſpects as is directed in the 16. Chapter of the Firſt Part of this Book.

Section V I.

Of Eaſt *and* Weſt Direct Reclining *Plans.*

IN Eaſt and Weſt Reclining Plains (the Latitude of the place, and Reclination being given) there are required the ſame three things as in North and South Erect Decliners, namely,

1. *The Height of the Pole (or Stile above the Plain.*
2. *The diſtance of the Subſtile from the Meridian.*
3. *The Plains difference of Longitude.*

Example, Of the Eaſt or Weſt Reclining Plain Part I. Chap. 10. whoſe Reclination was 35 deg. 00 min. and Latitude 51 deg. 32 min.

1. *For the height of the Pole (or Stile) above the Plain.*

As the Radius 90 deg.	10.00000
Is to the Sine of the Latitude 51 deg. 32 min.	9.89347
So is the Sine of the Reclination 35 deg.	9.75859
To the Sine of 26 deg. 41 min.	19.65206

Which 26 deg. 41 min. is the height of the Pole above the Reclining Plain.

2. *For the diſtance of the Subſtile from the Meridian.*

As the Radius 90 deg.	10.00000
Is to the Tangent of the Latitude 51 d. 32 m.	10.09991
So is the Co-fine of the Reclination 35 deg.	19.91336
To the Tangent of 45 deg. 52 min.	10.01327

Which 45 deg. 52 min. is the Subſtiles diſtance from the Meridian.

3. *For the Plains difference of Longitude.*

As the Sine of the Latitude 51 deg. 32 min.	9.89374

Is

Is to the Radius 90 deg.	10.00000
So is the Sine of the Subſtiles diſtance from the Meridan 45 deg. 52.	19.85595
To the Sne of 66 deg. 27 min.	9.96221

Which 66 deg. 27 min. is the Plains difference of Longitude.

Section VII.

Of South *and* North Declining Reclining *Plains.*

IN Declining Plains Reclining (beſides the Latitude of the place, Declination and Reclination of the Plain; which are for moſt part given) there muſt four things be found before you can draw the Dial, *viz.*

1. *The diſtance of the Meridian and Horizon.*
2. *The height of the Pole or Stile.*
3. *The diſtance of the Subſtile from the Meridian.*
4. *The Plains difference of Longitude.*

Of theſe Plains you have in the 20, 21, 22, 23, 24, and 25. Chapters of the Firſt Part Six Varieties, which are all that in any caſe may happen, *viz.* Three of South Declining Reclining, and as many of North Declining Reclining. I ſhall only inſtance in two of them, *viz.* one of a South Reclining Plain Declining Eaſterly, and another of a North Reclining Plain Declining Weſterly. The Example of the South Recliner ſhall be that in the third aud laſt Variety of South Decliners Reclining, and that is of a South Plain declining Eaſterly 30 deg. and Reclining 55 deg. as in Part I. Chap. 22.

I. *In* South Decliners Reclining.

1. *For the distance of the Meridian from the Horizon.*

As the Radius 90 deg. 10.00000

Is to the Sine of the Reclination 55 deg. 9.91336
So is the Tangent of the Declination 30 deg. 9.76144

To the Tangent of 25 deg. 19 min. 19.67480

Which 25 deg. 19 min. being taken from 90 deg. leaves 64 deg. 41 min. the distance of the Meridian from the Horizon.

2. *For the Height of the Pole (or Stile) above the Plain.*

This will require two Operations

1. As the Radius 90 deg. 10.00000

Is to the Sine of the distance of the Meridian from the Horizon 64 d. 41 min. 9.95615
So is the Co-Sine of the Reclination 35 deg. 9.75859

To the Sine of 31 deg. 14 min. 19.71474

Which 31 deg. 14. min. being less than the Latitude 51 deg. 32 min. substract it therefrom, and there will remain 20 deg. 18 min.

Then say again,

2. As the Sine of the distance of the Meridian from the Horizon 64 deg. 41 min. 9.95615
Is to the Sine of the Arch last found 20 d. 18 m. 9.54025
So is the Co-Sine of the Declination 60 deg. 9.93753

19.47778

To the Sine of 19 deg. 25 min. 9.52163

Which 19 deg. 25 min. is the height of the pole or Stile above the Plain.

Note, That if the Arch found at the first of these Operations be equal to the Latitude of the place (as there it was

was leſſer, *viz.* but 31 deg. 14 min.) then the Reclining Plain had been an Æquinoctial Decliner, and muſt be made as by the precepts delivered in the 20. Chap. of the Firſt Part.

3. *For the diſtance of the Subſtile and Meridian.*

As to the Co-Tangent of the Declination 60 d.	10.23856
Is to the Sine firſt found in the laſt proportion, *viz.* 31 deg. 14 min.	9.71477
So is the Tangent of the height of the Pole above the plain 19 deg. 25 min.	9.54714
	19.26191
To the Sine of 6 deg. 2 min.	9.02335

Which 6 deg. 2 min. is the diſtance of the Subſtile from the Meridian.

4. *For the Plains difference of Longitude.*

As the Sine of the difference of the Arch firſt found, and the Latitude of the place, *viz.* 20 deg. 18 min.	9.54015
Is to the Radius 90 deg.	10.00000
So is the Sine of the Subſtiles diſtance from the Meridian 6 deg. 2 min.	19.02335
To the Sine of 17 deg. 38 min.	9.48320

Which 17 deg. 38 min. is the plains difference of Longitude.

II. *In* North Decliners Reclining.

In all theſe Plains (as well as in South Recliners) four things muſt be found (beſides the Latitude of the place, and the Reclination of the Plain, which are commonly given) before the Dial can be drawn, and thoſe are the ſame as in South Recliners, *viz.*

1. *The diſtance of the Meridian from the Horizon.*
2. *The height of the Pole or Stile above the Plain.*

3. *The*

3. *The distance of the Substile from the Meridian.*
4. *The Plains difference of Longitude.*

All these may be found by the following *Canons* or *Analogies*. And for an Example, I shall make use of the North Plain Declining Westerly 60 deg. and Reclining 54 deg. as in the last Example of North Recliners, Part I. Chap. 25.

1. *For the distance of the Meridian from the Horizon.*

As the Radius 90 deg.	10.00000
Is to the Sine of the Reclination 54 deg.	9 90795
So is the Tangent of the Declination 60 deg.	10.23856
To the Tangent of 54 deg. 29 min.	10.14651

Which 54 deg. 29 min. being taken from 90 deg. leaves 35 deg. 31 min. And that is the distance of the Meridian from the Horizon.

2. *For the height of the Pole (or Stile) above the Plain.*

This also will require two Operations.

1. As the Sine of the Declination 60 deg.	9. 93753
Is to the Radius 90 deg.	10.00000
So is the Co-Sine of the distance of the Meridian from the Horizon 54 d. 29 m.	19.91059
To the Sine of 70 deg. 2 min.	9.97306

To this Sine of 70 deg. 2 min. add the Complement of the Latitude 38 deg. 28 min. the sum will be 108 d. 30 min. and this Arch (being above 90 deg.) take it from 180 deg. so will there remain 71 deg. 30 min.

2. As the Sine of the Arch first found 70 d. 2 m.	9.97306
Is to the Sine of the Reclination 54 d. 0 min.	9.90796
So is the Sine of the Arch last found 71 d. 30 min.	9.07695
	19.88491
To the Sine of 54 deg. 43 min.	9.91185

Which

Which 54 deg. 43 min. is the height of the Pole or Stile above the Plain.

Note, That if the Arch firſt found, *viz.* 70 deg. 2 min. had been juſt 90 deg. the plain then had been a polar declining Plain, the Subſtile and the hour of ſix being the ſame, and muſt be made by the Precepts delivered in Part I. Chapter 23.

3. *For the diſtance of the Subſtile and Meridian.*

As the Tangent of the Reclination 54 deg.	10.13874
Is to the Sine of the Arch firſt found *viz.* 54 deg. 29 min.	9.91059
So is the Tangent of the height of the pole above the plain 54 d. 43 min.	10.15021
	20.06080
To the Sine of 56 deg, 42 min.	9.92206

Which 56 deg. 42 min. or rather the Complement thereof to 180 deg. *viz.* 123 deg. 18 min. is the diſtance of the Subſtile from the Meridian, according as you pleaſe to account it, either from the North, or from the South.

4. *For the Plains difference of Longitude.*

As the Sine of the height of the pole above the plain 54 deg. 43 min.	9.91184
Is to the Tangent of the diſtance of the Subſtile and Meridian 56 deg. 42 min.	10.18251
So is the Radius 90 deg.	10.00000
To the Tangent of 61 deg. 48 min.	10.27067

Which 61 deg. 48 min. is the plains difference of Longitude counted from the North, or the Complement thereof to 180 deg. *viz.* 118 deg. 12 min. is the ſame difference of Longitude counted from the South.

Section

Section VIII.

Of the Hour Diſtances *upon the* Plains.

HItherto you have in a general, plain, and eaſie Method (and of all others the moſt exact) delivered, the manner how to calculate the requiſites belonging to all ſorts of Plains whether *Direct*, *Reclining*, *Declining*, or *both*. It reſteth now, to find the true hour diſtances one from another upon any of theſe Plains, and for that (for all Dials which have Centres) there is only one general *Analogy* or *Proportion*, and that is this. Having found the *Plains difference of Longitude*; ſay,

As the Radius or Sine of 90 deg.
Is to the Sine of the height of the Pole or Stile above the Plain.
So is the Tangent of each hours diſtance (upon the Æquinoctial) from the Subſtile,
To the Tangent of the ſame hours diſtance upon the plain counted for the Subſtile.

Now, (becauſe Examples do more confirm than barely Precepts) I ſhall by Preſident or Example make plain all that hath hitherto been delivered, and one ſhall ſerve inſtead of many, and that ſhall be in an Upright or Erect Declining plain, (which of all Dials are the moſt common and uſeful.) Suppoſe therefore,

In Latitude 52 deg. 40 min. *an Erect Plain beholding the South, to decline Weſtward* 24 *degrees*,

The Arithmetical Calculation.

By the Rules delivered in the III. *Section* of theſe *Precepts*, you ſhall find,

1. *The*

1. *The height of the Pole (or Stile) above the Plain to be* 33 deg. 38 min.
2. *The diſtance of the Subſtile from the Meridian to be* 17 deg. 14 min. And,
3. *The Plains difference of Longitude to be* 29 deg. 15 min.

Theſe Requiſites being thus attained, the next thing is to find the hour diſtances upon the Plain, which may be done by the laſt foregoing *Analogy*.

But firſt, you are to conſider the quantity of the Plains difference of Longitude, which here, in this Example, is found to be 29 deg. 15 min. And becauſe every hours diſtance upon the Equinoctial is 15 deg. diſtance from the Subſtile, or Meridian of the Plain; ſo 2 hours is 30 deg. diſtance, and 3 hours is 45 deg. diſtance: This Plains difference of Longitude being above 15 deg. (which is one hours diſtance) and leſs than 30 deg. (which is two hours diſtance) the Subſtile (the plain declining Weſterly) muſt needs fall between the hours of 1 and 2 in the Afternoon. Wherefore ſubſtract 15 deg. (1 hours diſtance) from 29 deg. 15 min. and there will remain 14 deg. 15 m. the Equinoctial diſtance of 1 a clock from the Subſtile. Alſo from 30 deg. (which is two hours diſtance) ſubſtract 29 deg. 15 m. and the remainer will be 00 deg. 15 min. for the Equinoctial diſtance of 2 a clock from the Subſtile. Having found the Equinoctial diſtances of the two next hour-lines on either ſide of the Subſtile (as of 1 and 2) the reſt are eaſily found by the continual addition of 15 deg. and ſo is the Column of the Equinoctial diſtances in the following Table made. Being thus prepared, the true hour diſtances from the Subſtile upon the Plain may eaſily be attained by the foregoing *Analogy*. I will inſtance in one hours diſtance for all, and give you the reſt in a Table: As,

Let it be required to find the diſtance of one a Clock upon the Plain from the Subſtile, Say,

As the Sine of 90 deg. 1000000

Is to the Sine of the height of the Stile 33 deg. 38 min. } 9.74341

So is the Tangent of the Equinoctial diſtance of one a clock, *viz.* 14 deg. 15 min. } 9.40478

To the Tangent of 8 deg. 0 min. 19.14819

Which 8 deg. 0 min. is the diſtance of the one a clock hour-line upon the Plain from the Subſtile. And in the ſame manner may you find the diſtance of 2 a Clock to be 0 deg. 25 min. Of 3 a clock 8 deg. 53 m. Of 4 a Clock 18 deg. 14 min. and ſo the reſt, as in the following Table for every whole hour. And if you deſire halfs and quarters of hours, you muſt inſert them in the Column of Equinoctial diſtances, allowing 7 deg. 30 min. for half an hour, and 3 deg. 45 min. for a quarter, and ſo 15 deg. for a whole hour.

Hours	Equinoctial diſtances		True hour diſtances		
	deg.	min.	deg.	min.	
VIII	89	15	88	39	
IX	74	15	63	1	
X	59	15	42	57	
XI	44	15	28	21	
XII	29	15	17	14	
I	14	15	8	0	
Subſtile II	0	45	0	25	Subſtile
III	15	45	8	53	
IV	30	45	18	14	
V	45	45	29	37	
VI	60	45	44	41	
VII	75	45	65	22	

Thus

Thus have you the Arithmetical Calculation of the whole Dial; it remains now to ſhew how theſe hour-lines are to be transferred from the Table to the Dial-plain, which is to be done as followeth.

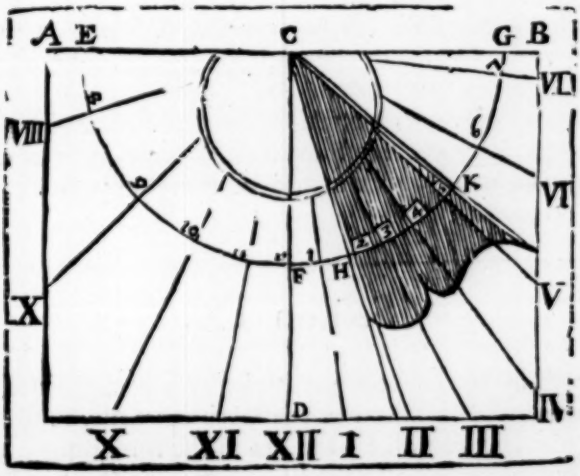
The Geometrical Projection.

Firſt, (Upon your Dial-plain) draw an Horizontal-line A B, and perpendicular thereunto another line C D, for the Meridian and Hour-line of 12.

Secondly, Take 60 deg. out of your line of Chords, and ſetting one foot in C, with the other deſcribe the Semicircle E F G.

Thirdly, Becauſe the diſtance of the Subſtile from the Meridian was found to be 17 deg. 14 min. take 17 d. 14 m. from your Line of Chords, and ſet them upon the Semicircle from F to H, and draw the Line C H for the Subſtile.

South Declining Weſt 24 *degrees*, *Latitude* 52 *deg.* 40 *min.*



Fourthly, The height of the Stile being 33 deg. 38 min. ſet that diſtance upon the Semicircle from H to K, and draw the Line C K for the Stile.

Fifthly, (Having recourſe to your Table) take 18 deg. 39 min. out of your Line of Chords, and ſet them upon the Semicircle from H to 8, and draw the line C 8 for the Hour-line of 8 of the Clock.

Laſtly, From your line of Chords, take

deg.	min.
63	1
42	57
18	21
17	14
8	0
0	25
8	53
18	14
29	37
44	41
65	22

and ſet the ſame upon the Semicircle upon the Plain, from H, to

9
10
11
12
1
2
3
4
5
6
7

and draw the lines

C 9
C 10
C 11
C 12
C 1
C 2
C 3
C 4
C 5
C 6
C 7

for the Hour-lines.

Thus is your Dial finiſhed, only the Stile, which muſt be ſet to hang perpendicularly over the Subſtile, making an Angle at the Centre of the Plain of 33 deg. 38 min. equal to the height of the Stile.

And thus have you an Abſtract of *The whole Art of Dialling*, after the moſt exact and compendious way of performance; others may be more expeditious, but none more exact.

Section IX.

IT will be to little purpoſe to be thus curious in finding of the true Poſitions of the Meridian, Stile, Subſtile and Hour-diſtances in all Plains, as in the foregoing Precepts is delivered, unleſs alſo we be as ſevere or ſtrict in finding of

of the Site or Poſition of the Plain, upon which the Dial is to be made. For what will it ſignifie to make the Dial true, and place it in a wrong Poſition? You are in the Geometrical Part of this Book taught how to find the Declination of any Plain, and for the finding of it, to attain the true *Azimuth* of the Sun is the chief Ingredient, and how to perform that Geometrically, is there taught two ways. But that the like exactneſs may be in the performance of this alſo, I ſhall in this place (before I end) exhibit the manner of finding the Sun's Azimuth at any time, and in any place, by Arithmetical Calculation.

Example, In the *Latitude* of 51 deg. 32 min. the Sun having 17 deg. 56 min. of *North Declination*, and his *Altitude* 35 deg. Let it be required to find his *Azimuth*.

Firſt, Add the Complement of the Latitude, the Complement of the Declination, and the Complement of the Suns Altitude all into one Sum, and take the half thereof, from which half Sum ſubſtract the Complement of the Declination, and note the difference as here is done.

	deg.	min.		deg.	min.
Latitude	51	32	Complement	38	28
Declination	17	56		72	04
Altitude	35	00		55	00
			ſumm	165	32
			half ſumm	82	46
The difference between the half ſumm and the Complement of the Declination.				10	42

Then will the proportion be

(1.) As the Radius 90 deg.	10 00000
Is to the Co-ſine of the Altitude 55 deg.	9.91336
So is the Co-ſine of the Latitude 38 d. 28 m.	9.79383
To the Sine of 30 deg. 38 min.	9.70719

(2.) As

(2.) As the Sine of 30 deg. 38 min.	9 70719
Is to the Sine of the half ſum 82 d. 46 m.	9.99653
So is the Sine of the difference 10 d. 42 min.	9.26873
	19.26526
To this Sine	9.55807
To which add the Radius or Sine of 90 d.	10.00000
The Sum is	19.55807
The half Sum	9 77903

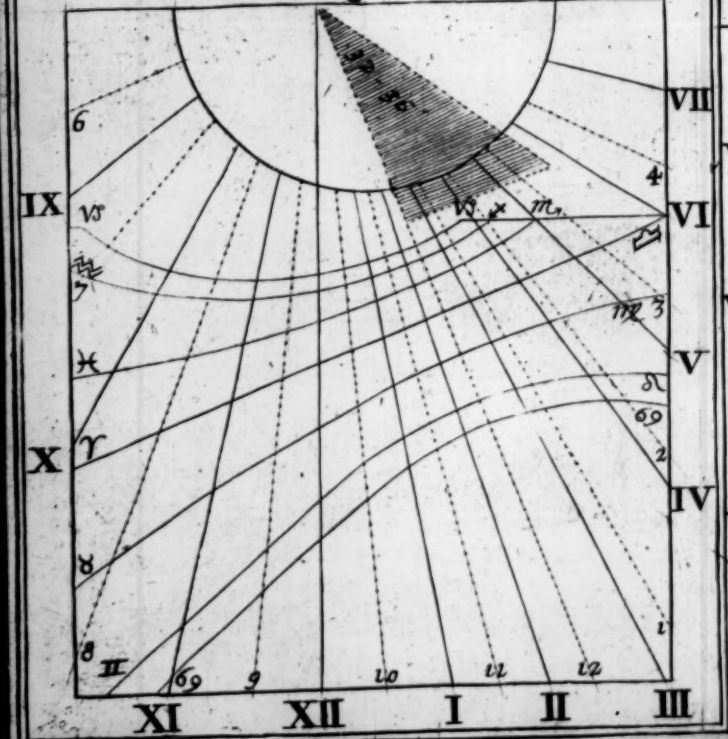
Which is the Sine of 36 deg. 58 min. the Complement whereof is 53 deg. 2 min. and that doubled is 106 d. 4. m. which is the Suns Azimuth from the North part of the Meridian, which if you take from 180 deg. there will remain 73 deg. 56 min. which is the Azimuth from the South. And thus may you find the Sun's *Azimuth* moſt exactly at any time.

POSTSCRIPT.

IN the foregoing Treatiſe, you have Four ſeveral ways of making all manner of Plain Sun Dials, viz. *Two Geometrical, one Inſtrumental, and a Fourth performed by Arithmetical Calculation: It might here be expected, that I ſhould now ſhew how to adorn and beautifie theſe Dials with various Furniture relating to the Sun's Courſe; I having done ſomething (long ſince) of that Nature in another place: And to treat of them here, would have much enhaunced the Price of the Book, the Engraving and Printing Copper Schemes being very Chargeable: But to ſatisfie ſuch as are delighted with Curioſities of this Nature, the Author hereof, hath now in the Preſs, a Book in* Folio *Entituled,*

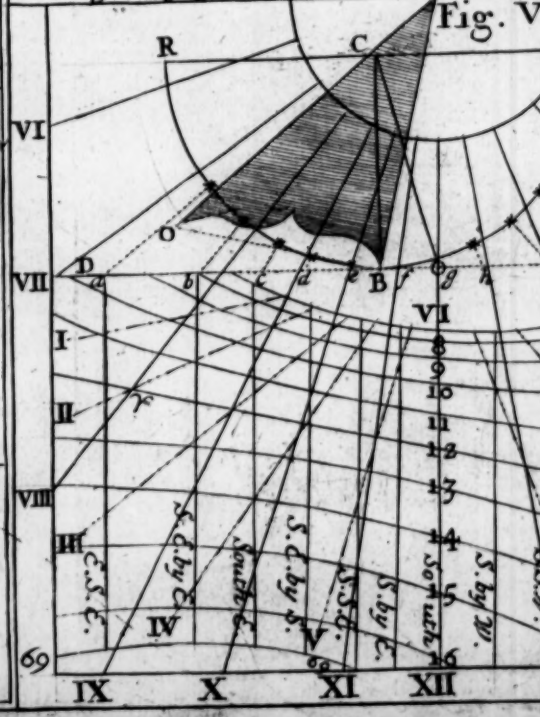
AD-

Fig. V.



A Declining Diall, with Pa
Length of ☿ Day, Azimuths, and

Fig. V



h Parallels of the
s, and Iewish Hours.

Fig. VI.

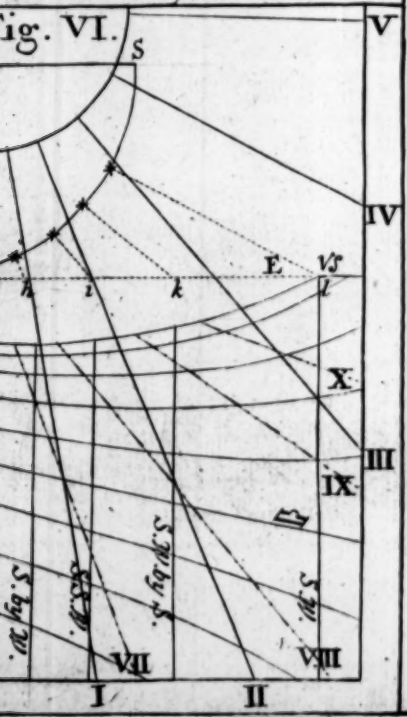


Fig. VII.

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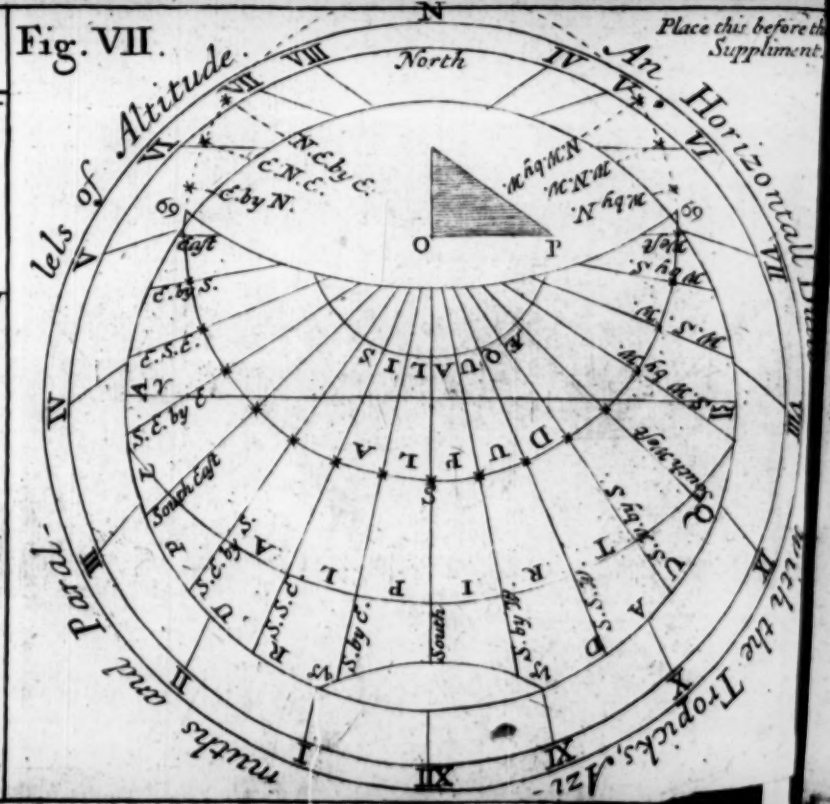
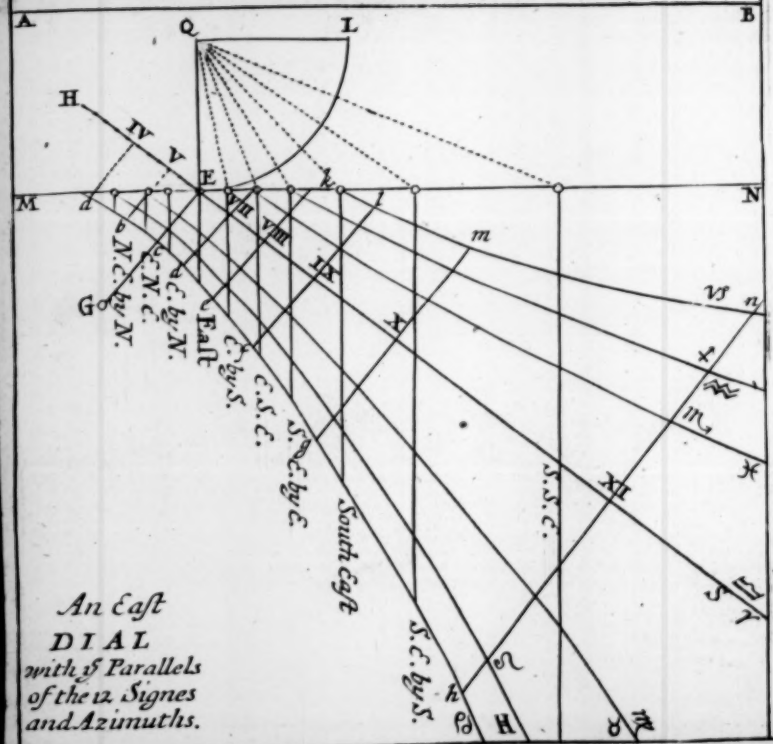


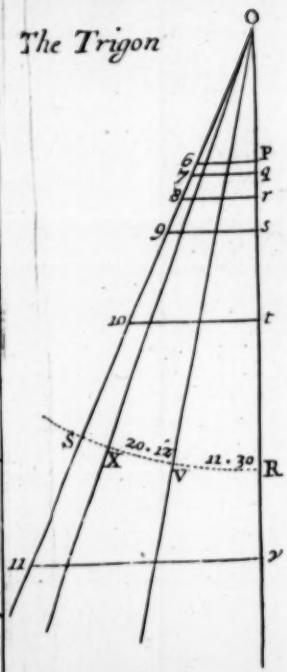
Fig. I.



An East
DIAL
with 5 Parallels
of the 12 Signes
and Azimuths.

Fig. II.

The Trigon

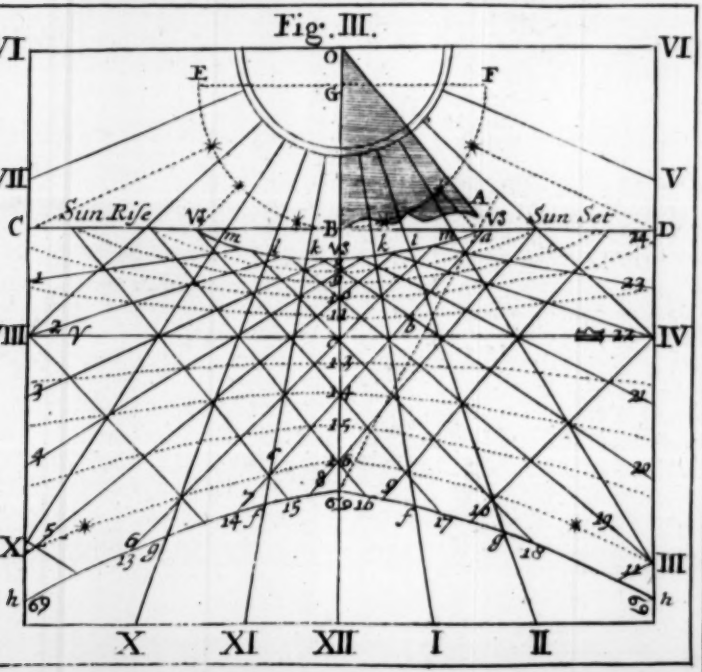


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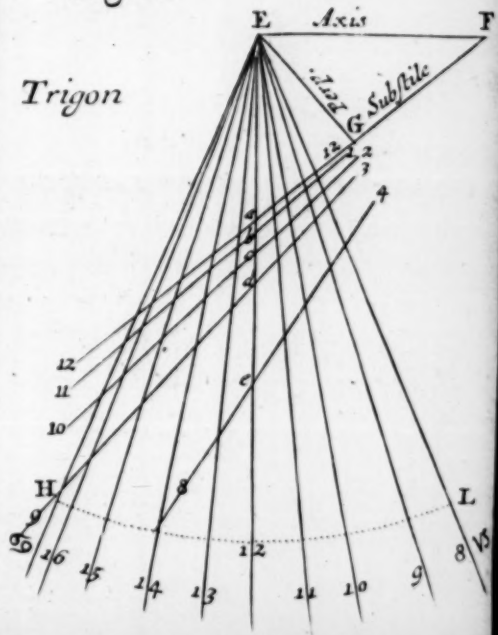
A South Dial with the Babylonish and Itallian Hours & Diurnall Arches.

Fig. III.



Place this before the Supplement.

Fig. IV.



A SUPPLEMENT TO Geometrical Dialling, &c.

CHAP. I.

Of ſuch Circles *of the* Sphere, *as are deſcribed upon* Sun-Dials.

MAny *Aſtronomical* Concluſions may be performed by deſcribing of the *Circles* of the *Sphere* upon *Dial-Plains*; of which I have here made choice of theſe following:

1. The *Parallels* of the *Signs*, ſhewing in what part of the *Zodiack* the Sun is at all times of the year.

2. The *Diurnal Arches*, ſhewing the length of the *day* and *night* throughout the *year*.

3. The *Hours* from the *Sun's Riſing*, or *Setting*; or the *Babyloniſh* and *Italian Hours*.

4. The *Unequal*, *Jewiſh*, or *Planitary* hours.

5. The *Azimuths*, or *Vertical Circles*, ſhewing in what quarter of the *World*, or upon what *Point* of the *Mariners Compaſs*, the Sun is at all times of the Day.

6. The *Almicanters*, or *Circles* of *Altitude*; whereby the *Proportion* of *Shadows* to their *Objects*, or the *Sun's height* may be known.

Of theſe ſome are *great Circles* of the *Sphere*, others *ſmall*: The *great Circles* in all Plains are repreſented by *ſtreight lines*, as the *hour-lines* themſelves are: The *leſſer Circles* are deſcribed by *Conick Sections*; and they are either *Parabolas*, *Hyperbolas*, or *Ellipſes*: Only the *Parallels* of the *Signs*, and the *Diurnal Arches* in *Polar Dials*, and the *Parallels* of *Altitude* in *Horizontal Dials*, and perfect Circles.

CHAP. II.

How to deſcribe the Equinoctial, *the two* Tropicks, *and other intermediate* Parallels *of* Declination, *upon any Dial Plain.*

THe two *Tropicks* being the Boundaries of the *Sun's Courſe*, (for he never exceeds thoſe Limits,) I count it beſt, firſt to ſhew how they may be deſcribed; for that between them all other *Circles* (either *great* or *ſmall*) muſt be *projected*, and the manner of deſcribing them upon ſeveral Plains is various.

In a *Polar Dial* they are perfect *Circles*, and ſo are eaſily deſcribed by *Circles* drawn about the foot of the *perpendicular ſtile*; in all other Plains they are *Sections* of a *Cone*.

I. *In the* Equinoctial, *and direct* Eaſt *or* Weſt *Dials.*

Let an Example be of a direct *Eaſt Dial* in the Latitude of 51 *d.* 32 *m.*

How to deſcribe the *hour-lines* upon theſe Plains is ſhewed in the ſixth Chapter of this Book. Wherefore ſuch a Dial

a Dial being drawn as in Figure I. through the *foot* of the *perpendicular ſtile* at E, draw a right Line M E N, *Parallel* to the *Horizon*; for the *Horizontal Line*, in all Plains, muſt be drawn through the foot of the *perpendicular ſtile*, and alſo through the Point where the *Equinoctial Circle* croſſeth the *Hour-Line* of *Six*. Your Dial, with the *Equinoctial* Line thereof, H E S, being drawn, come we to deſcribe the *Tropicks*: To effect which,

Firſt, Upon a piece of fine *Card-Paiſt-Board* draw a right Line O R, as in Figure II. repreſenting the *Equinoctial* Line in your Dial; and (becauſe the *Tropicks* are 23 deg. 30 min. diſtant from the *Equinoctial*) with 60 deg. of your *Chords*, upon the point O, deſcribe an Arch of a Circle, and upon it ſet 23 deg. 30 min. from R to S, and draw the Line O S, repreſenting the two *Tropicks*; and this Angle S O R, I call a *Trigon*.

Secondly, Out of your Dial take the length of the *perpendicular Stile* E G, and ſet it upon the *Trigon* from O to P, and draw the Line P 6 perpendicular to O R: Alſo

Take the diſtance from G, to the Interſection of the Hour-Line of	7 8 9 10 11	with the Equinoctial, and ſet them upon the Trigon from O, to	*q r s t v*	and draw the Lines	*q r s t v*	7 8 9 10 11	perpendicular to O R.

Having thus prepared the *Trigon*, out of it take the diſtance P 6, and ſet it upon the 6 a clock *hour-line*, from E to *c*: —— Alſo take the diſtance *q* 7, and ſet it upon your Plain from V to *b*, and from VII to *d*: —— Alſo take *r s*, and ſet it on your Plain from IV to *a*, and from VIII to *e*: —— Likewiſe take the diſtance *s* 9, and ſet it upon your Plain from IX to *f*: —— Alſo take the diſtance 10 *t*, and ſet it from X to *g* — Laſtly, take *v* 11, and ſet it on the Plain from XI to *h*.

Theſe

Theſe Points *a, b, c, d, e, f, g, h,* are the Points through which the *Tropick of Cancer* muſt be deſcribed; wherefore, if through them a line be drawn with an even hand, making no Angles, that ſhall be the *Tropick* of *Cancer.*

The *Tropick* of *Capricorn* may be deſcribed in the ſame manner, for if from your *Trigon* you take

The diſtance	8	*r*	And ſet it upon your *Dial-Plain* from	VIII	*k*
	9	*s*		IX	*l*
	10	*t*		X	*m*
	11	*v*		XI	*n*

Thoſe ſhall be the Points through which the *Tropick* of *Capricorn* muſt be deſcribed; wherefore if through *k l m n,* a line be drawn with an even hand, it ſhall repreſent the *Tropick* of *Capricorn*:

And whereas I ſaid before, that the two *Tropicks* are the Boundaries of the *Sun's Courſe,* you are to Note, That

When the Sun is in	*Capricorn,*	which is about	*Decem.* 11.	the ſhadow of the top of the *Stile* will paſs along thoſe reſpective Lines.
	Aries, or		*March,* 10.	
	Libra,		*Sept.* 12.	
	Cancer,		*June,* 11.	

And according to this Method may any other intermediate *Parallels* of *Declination* be inſerted; as for *Example*: Suppoſe I would inſert the *Parallels* of the *Sun's* entrance into the 12 *Signs, Aries* and *Libra* are inſerted already, alſo *Cancer* and *Capricorn*; for the reſt, as when the Sun enters into

Taurus,

Taurus, *Virgo*, *Scorpio*, *Piſces*, } the Sun hath 11 deg. 30 min. }
Gemini, *Leo*, *Sagittarius*, *Aquarius*, } the Sun hath 20 deg. 12 min. } of Declination,

Wherefore take 11 deg. 30 min. and 20 deg. 12 min. out of your Line of Chords, and ſet them upon Arch R S of your *Trigon*, from R to V and X, and draw the two Lines O U and O X.

Theſe *Parallels* being thus put into your *Trigon*, they may be transferred into the *Dial Plain*, in all reſpects, as the *Tropicks* were; and as you ſee done in the Figure I.

II. *In a* Direct North *or* South *Dial.* Figure III.

Having drawn your *Dial* as is taught in Chapter V. together with the *Stile*, your firſt work muſt be to *proportion your Stile to your Plain*; which to doe, aſſume any convenient point in the *Subſtile* (here the Line of XII) for the farthermoſt *Tropick*, as here the Point ♋; then the *Stile's* height being 38 deg. 28 min. add 23 deg. 32 min. thereto, the Summ is 62 deg. and that isthe *Meridian Altitude* of the *Sun* when he enters *Cancer*, and the Complement thereof is 28 deg. wherefore, upon the Point *Cancer*, make an Angle B ♋ A to contain 28 deg. ſo ſhall the Line ♋ A cut the *Axis* of the *Stile* O A, in A; then from A let fall a Perpendicular to O ♋, as A B; and ſo is your *Stile* proportioned to your *Plain*; and the Line C B D, (being drawn *Parallel* to the *Horizon*, through the Point B) ſhall be the *Horizontal Line* of the *Plain*.

This

This done, prepare a *Trigon*, as Figure IV. in which make E F equal to O A, and F G equal to O B, and E G, to A B, the *Triangle* E F G in the *Trigon*, equal to the *Triangle* of the *Stile* O A B in the *Dial*.

From the Point E draw a Perpendicular to E F, as E 12, for the *Equinoctial*; and upon E, with 60 deg. of your *Chord* deſcribe an Arch H 12 L, and upon it ſet 23 deg. 30 min. from 12 to H and L, 4 drawing the Line E H for the *Tropick* of *Cancer*, and E L for the *Tropick* of *Capricorn*:

Draw the *Subſtilar* Line F G quite through the *Trigon*, croſſing the *Equinoctial* in *a*, and both the *Tropicks*.

This done, out of your *Trigon* take the diſtance from F to *a*, and ſet it upon the *Dial plain* from the *Center* O to *c*, through which Point *c* draw the right Line ♈ *c* ♎ for the *Equinoctial*: Then from O, the Center of your *Dial*, take the diſtance to the interſection of the *Hour-Line* of 11 or 1 with the *Equinoctial*, and ſet that diſtance upon the *Trigon* from F to *b*: — Alſo take the diſtance from O, to the interſection of the Hour-Line of 10 or 2, and ſet it from F to *c*: —— Likewiſe the diſtance from O, to the interſection of the Hour-Line of 9 or 3, ſet from E to *d*: —— And laſtly, the diſtance from O, to the interſection of 8 or 4, with the *Equinoctial*, ſet from F to *e*; and draw the Lines F *a*, F *b*, F *c*, F *d*, F *e*, through the *Trigon*, marking them with 12, 11, 10, 9, 8 and 1, 2, 3, 4, &c.

Now to find the Points upon the *Plain*, through which the *Tropicks* muſt paſs;

The Diſtance from F to	12	will reach from O, the Center of the *Dial*, to	♋	on the Hour-Lines of	12	
	11		*f*		11	1
	10		*g*		10	2
	9		*h*		9	3
	8					

Through

Through which points the *Tropick* of *Cancer* muſt be drawn with an even hand: And,

The diſtance from F to	12	will reach from O, the *Center* of the *Dial*, to	♈	upon the Hour-lines of	12	12
	1		*k*		11	1
	2		*l*		10	2
	3		*m*		9	3
	4		♑		8	4

Through which Points the *Tropick* of *Capricorn* muſt be drawn. And thus have you the *Equinoctial*, and the two *Tropicks*, deſcribed upon a direct South Plain.

III. *How to deſcribe the* Equinoctial, *and the two* Tropicks *into any* Upright Declining Plain; *or into ſuch as both* Recline *and* Decline.

Our *Example* ſhall be in an *Upright Plain*, declining from the *South Weſtward* 30 deg. The making of theſe Dials is taught in the VII. and VIII. Chapters of this Book: Wherefore, having drawn ſuch a *Dial*, with the *Stile* and *Subſtile* in a due *Poſition*, you ſhall find the height of the *Stile* to be 32 deg. 36 min.

Firſt, Make an *Horizontal Dial* for the Latitude of 32 deg. 36 min. as is the *Declining Dial* Fig. V, where the *Subſtilar Line* is taken for the Hour-Line of 12, as it is there marked, and the other Pricked-Lines, and the Hour-Lines of an *Horizontal Dial* for the Latitude of 32 deg. 36 min. Now, if according to the directions of the foregoing *Section*, you make a *Trigon*, and inſert the *Equinoctial* and *Tropicks*; and afterwards expunge the obſcure Lines of the *Horizontal Dial*, the *Equinoctial*, *Tropicks*, and *Horizontal Line* will be the ſame, as if they had been inſerted from the true Hour-Lines belonging to the Plain.

And as the *Tropicks* were deſcribed, ſo likewiſe may the *Parallels* of the Sun's Entrance into the other Signs, be inſerted, if into your *Trigon* you put the *Arches* of their *Declinations* from the *Equinoctial*, namely 11 deg. 30 min. and 20 deg. 12 min. And ſo are the *Parallels* of the *Signs* put into this *Dial*, Fig. V——

And in any *Dial* alſo may the *Diurnal Arches* be deſcribed, if you put into the *Trigon* ſuch *Declinations* as the Sun hath from the *Equinoctial*, when the Day is either

				deg.	min.
♈	♎	Hours long, as		23	30
8	16			21	40
9	15			16	55
10	14			11	37
11	13			5	55
12	12			00	00

or

And ſo are the *Diurnal Arches* put into the South-Plain, repreſented by the Pricked lines there, in Fig. III, and the *Trigon* thereunto belonging Fig. IV.

CHAP. III.

How the Hours *from the* Sun's Riſing *and* Setting *are to be inſcribed into all ſorts of* Dial-Plains.

THe *Hours* from *Sun-Riſing* are called the *Babyloniſh Hours*, for that they begin their Day at the *Sun's Riſing*; and the *hours* from *Sun-Setting* are called the *Italian hours*, for that in *Italy* they account their *Time* from the *Setting* of the *Sun* the day preceding.

The manner how to inſcribe theſe *hours*, is the ſame in all Plains, and is eaſily performed: And becauſe that upon

on a full *South*, or *Horizontal Plain*, they will appear moſt uniform; I have therefore made choice of a direct *South Dial*, as is Fig. III. to inſcribe them:

Your *Dial* being drawn, and the *Equinoctial*, ♈ ♎, the two *Tropicks*, and ♋ ♋, and ♑ ♑, and the *Horizontal-Line*, *Sun Riſe*, *Sun Set*; you muſt (by the laſt Chapter) deſcribe two obſcure *Parallels* of *Declination*, one when the Day is 8 hours long, as ☉ 8 ☉, and the other when the Day is 16 hours long, as ✱ 16 ✱, the *Equinoctial* being the *Parallel* when the Day is 12 hours long.

Being thus far prepared, the inſcription of theſe *hours* will be very eaſie; for it is plain, that when the day is but 8 hours long, that the *Sun riſes* at 8 in the Morning; and the firſt line after the *Sun's Riſing* is 9 in the Morning; —— Alſo when the day is 12 hours long, the *Sun Riſes* at 6 in the Morning, and the firſt hour after is 7 in the Morning; —— Laſtly, When the Day is 16 hours long, the *Sun riſes* at 4 in the Morning, and the next hour after is 5 in the Morning: —— And all the reſt as in this Table. Wherefore, a ſtreight line drawn through the interſections of theſe hour-lines, with the *Parallels* of 8, 12 and 16 hours, ſhall be the firſt hour after the *Sun Riſing* all the year long.

Hours from Sun Riſing	*Length of the Day.* VIII	XII	XVI
I	9	7	5
II	10	8	6
III	11	9	7
IV	12	10	8
V	1	11	9
VI	2	12	10
VII	3	1	11
VIII	4	2	12
IX	5	3	1
X	6	4	2
XI	7	5	3

In like manner, if you would inſert the ſeventh hour after the *Sun Riſing*: By the Table you ſee, that in the *Parallel* of VIII hours, for the length of the Day, the ſeventh hour from *Sun Riſing* is 3 in the afternoon; therefore obſerve where the hour-line of 3 croſſeth the *Parallel* of VIII hours, which is at *a*. —— Alſo by the Table you ſee that in the *Parallel* of XII hours, for

the length of the day, the ſeventh hour from *Sun-Riſing* is 1 in the Afternoon; wherefore obſerve where the hour-line of I croſſeth the *Equinoctial*, which is at *b.* —— Thirdly, By the Table you ſee, that in the *Parallel* of XVI hours, for the length of the Day, the ſeventh hour from the Sun's Riſing is 11 in the Forenoon; and therefore obſerve where the hour-line of XI croſſeth the *Parallel* of XVI hours, for the length of the day, which is at *c*; ſo ſhall a right-line, drawn through theſe three Points, *a*, *b*, *c*, be the ſeventh hour after the Sun's Riſing throughout the year: And thus by help of this little Table, may all the hour-lines from the Sun's Riſing be drawn as you ſee them drawn, and numbred, as in Fig. III.

In the ſame manner, as the hours from the Sun's Riſing (which are the *Babyloniſh* hours) were drawn, may the hours from the Sun's Setting (which are the *Italian* hours) be drawn: The difference being only in the numbering of them; the hours from Sun-Riſing being numbred from the *Weſt* end of the *Horizontal-line*, by 1, 2, 3, 4, 5, 6, 7, 8, 9, 10: And the hours from Sun-Setting from the *Eaſt* end of the *Horizontal-line* backwards, by 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13; all which is evident in the forenamed Fig. III.

COROLLARY.

The hour-lines from Sun-Riſing and Setting being deſcribed upon any Dial-Plain, as is before taught, there will by their correſpondent interſections one with another, be Points produced, through which if Lines be drawn with an even hand, the ſame ſhall be the *Parallels* of the Length of the Day, and ſuch are the Pricked Lines in Figure III, numbred upon the Meridian-Line of the *Dial*, by 8, 9, 10, 11, 12, 13, 14, 15, 16.

CHAP.

CHAP. IV.

Of the Jewiſh, *or Old* Unequal, *or* Planitary-hours, *and how they may be inſcribed upon any* Dial-Plain.

THe Ancients account of their day, was from the Sun's Riſing in the Morning, till it's Setting in the Evening, which ſpace of time they did divide into twelve equal Parts, were it long or ſhort: So that in the Summer all that time that the Sun hath *North-Declination*, the hours of their day were longer then a Common equal hour; and in the Winter, when the Sun hath *South-Declination*, the hours of their day were ſhorter than a common hour; but when the Sun is in the *Equinoctial*, their hours are equal to our Common hours.

The Inſcription of theſe hour-lines into all ſorts of Plains is very eaſie, being much like the Inſcription of the *Italian* and *Babyloniſh* hours, taught in the laſt Chapter.

Having

The Jewiſh,	*The* Parallel *of* 15 *hours.*		*Equinoctial.*	*The* Parallel *of* 9 *hours.*	
Hours	*Ho.*	*Min.*		*Ho.*	*Min.*
I	5	45	7	8	15
II	7	0	8	9	0
III	8	15	9	9	45
IV	9	30	10	10	30
V	10	45	11	11	15
VI	12	0	12	12	0
VII	1	15	1	0	45
VIII	2	30	2	1	30
IX	3	45	3	2	15
X	5	0	4	3	0
XI	6	15	5	3	45
XII	7	30	6	4	30

Having drawn your Dial, with hours, halfs, and quarters; and alſo the *Equinoctial*, the two *Tropicks*, and *Horizontal* Line; and alſo the *Parallels* of the length of the day, as is done in Figure VI, which is a *South* Dial declining *Eaſtward* 15 deg. you muſt make choice of two *Parallels* of the length of the Day, which muſt both of them be equidiſtant from the *Equinoctial*, which let be the *Parallels* of 9 hours, and 15 hours, for thoſe two *Parallels* are moſt convenient for this purpoſe; becauſe the *Jewiſh* hours in thoſe *Parallels* will juſtly fall upon the even hours, halfs, or quarters: Now the Points through which the *Jewiſh* hours are to be drawn, this Table will direct to; wherein you ſee, that the firſt *Jewiſh* hour is to be drawn through 5 hours, 45 min. in the *Parallel* of 15 hours, through 7 in the *Equinoctial*, and through 8 hours and 15 min. in the *Parallel* of 9 hours: ——In like manner the ſecond *Jewiſh* hour muſt be drawn through the interſection of the 7 hours in the *Parallel* of 15 hours, through 8 in the *Equinoctial*, and through 9 in the *Parallel* of 9 hours: And ſo muſt all the reſt of them be deſcribed as the Table does direct, and as you ſee done in Figure V. And in this manner, by help of this Table, may they be deſcribed in all ſorts of Plains, whither Direct, Reclining, or Declining.

CHAP.

CHAP. V.

How the Azimuths, *or* Vertical Circles, *are to be inſcribed upon* Dial Plains.

THe *Azimuths* are great Circles, and being Projected upon all Plains, become ſtreight Lines; and they are variouſly deſcribed, according as the Plain is ſituated; particulars of which follow.

SECT. I.

On an Horizontal *Plain.*

IN theſe Plains theſe *Azimuths* are moſt eaſily inſerted: For, your Dial being drawn, with the *Tropicks* and *Azimuths* thereupon, you have no more to doe, then upon the foot of the perpendicular Stile at O (in Figure VII) as a Centre, to deſcribe a Circle, as *S* ☉, *N* ☾, which you may divide into 32 equal Points (beginning at *N*) anſwering to the 32 Points of the Mariner's Compaſs, (or elſe you may divide it into 90 equal parts, or degrees,) noted with ***, &c. and through thoſe Points draw ſtreight Lines from O, the foot of the perpendicular Stile, and they ſhall be the true *Azimuths* upon the *Horizontal* Plain; which you may denominate by *South*, *S* by *E*, *S S E*, *S E* by *S*, &c. as you ſee done in Figure VII.

SECT.

SECT. II.

Upon an Erect, Direct East, *or* West *Plain, Figure I.*

HAving made an *East* Dial, and therein inſerted the *Equinoctial*, the two *Tropicks*, and the *Horizontal* Line, you may proceed to the Inſcription of the *Azimuths* in the manner following.

Upon the Point E, of the *Horizontal* Line of the Plain M E N, erect the Perpendicular E Q, equal to E G, (the height of the Stile of your Dial,) and upon Q, as a Centre, deſcribe the *Quadrant* Q E L, and divide it into eight equal parts, repreſenting one quarter of the Mariner's Compaſs, and from Q, through thoſe Points, draw Lines to the *Horizontal* Line M E N, noting them with ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ; from which Points let fall Perpendiculars from the *Horizontal* Line, and they ſhall be the *Azimuths* between the *South* and the *Eaſt* ; —— And for thoſe Points which fall between the *Eaſt* and the *North* ; namely *E* by *N*, —— *E N E*, —— *N E* by *N*, —— the ſame diſtances being ſet upon the *Horizontal* Line from E, towards the Left hand, as the three firſt *Azimuths*, *E* by *S*, —— *E S E*, —— *S E* by *E*, were towards the Right hand, ſhall give the three Points ⊙ ⊙ ⊙ on the Left hand of E ; through which Points alſo Lines drawn Perpendicular to the *Horizon*, ſhall be the *Azimuths*, or Points of the Compaſs between the *Eaſt* and the *North*: As in the Fig. I. And as the *Eaſt* Dial contains the *Azimuths* between the *South* and the *Eaſt*: The *Weſt* Dial muſt contain thoſe between the *South* and the *Weſt*.

SECT.

SECT. III.

Upon a direct South *upright Plain.* Figure *III.*

THe Dial, with the *Equinoctial*, the two *Tropicks*, and the *Horizontal* Line deſcribed thereon, the *Azimuths* may be inſerted thereon as followeth:

Firſt, Take the length of the *perpendicular Stile* of your Dial A B, and ſet it upon the *Meridian* of your Dial from B to G.

Secondly, With the diſtance G B, upon G, deſcribe the *Semicircle* E B F, which divide into 16 equal parts, (if you will,) but I have here divided it but into 8, to ſhew the manner of the Work, in the Points * * * * &c. through which Points from G, draw obſcure lines, extending them till they touch the *Horizontal* Line of the Plain C B D; now if from theſe Points of touching you draw lines *perpendicular* to the *Horizontal* Line between the *Tropicks*, or *Parallel*, to the line of 12, they ſhall be the *Azimuths* required.

I have not drawn the lines themſelves in this Fig. III. becauſe the Plain is full enough of Lines already.

SECT. IV.

Upon a South *Declining Plain.* Fig. VI.

AN Example ſhall be of a *South* Plain, declining Eaſtward 15 deg.

Such a Dial being drawn, and the *Equinoctial Tropicks*, and the *Horizontal* Line inſcribed thereon: Upon the

Point B of the *Horizontal* Line erect the *perpendicular* B C, equal to B O, the *perpendicular* Stile of your Dial; upon which Point C deſcribe the *Semicircle* R B S; which done, lay a Ruler to C, and the Point ⊙, where the hour line of 12 croſſeth the *Horizontal* Line, and where the Ruler cuts the *Semi-circle* R B S, at that Point begin to divide it into 16 equal parts, at the Points *** &c. and from the Center C draw lines through thoſe Points, extending them till they touch the *Horizontal* Line D E, in the Points *a b c d e f g h i k* and *l*, through theſe Points right lines being drawn *Parallel* to the *Meridian*, ſhall be the *Azimuths* deſired, which you muſt number according to the ſituation of the Plain: Namely, the Weſtern *Azimuths* on the Eaſt ſide of the *Meridian*, and the *Eaſt Azimuths* on the *Weſt* ſide of the *Meridian*, as you ſee them numbred in Fig. VI.

CHAP. VI.

How to inſcribe the Circles of the Sun's Altitude into Dial-Plains.

THE *Almicanters*, or Circles of *Altitude*, in the *Sphere* have the ſame habitude to the *Azimuths*, or Vertical Circles, as the *Parallels* of declination have to the *Meridians*, or Hour-Circles: And therefore, the *Equinoctial* it ſelf, and all the *Parallels* of declination in a *Polar* Plain, and perfect Circles, and ſo are the *Almicanters*, or Circles of *Altitude*, upon an *Horizontal* Plain, as in Fig. VII.

Horizontal Plains, which lie *Parallel* to the *Horizon*, have the *Zenith* for their Poles: ſo that for the inſcription of them upon theſe Plains, the foot of the *perpendicular* Stile muſt be the Centre upon which to deſcribe them.

For

For the *Numeration* of theſe Circles when they are deſcribed, there are two ways moſt in Uſe: The one by Degrees and Minutes of the Sun's *Altitude*; the other according to the proportion that the height of any upright *Object* (as a Houſe, Steeple, &c.) bears to the ſhadow of it: The laſt of which I have here followed in this Figure VII. where the Circles of *Altitude* are equal, double, triple, and quadruple to the *Altitude* of the *perpendicular* Stile.

The inſcription of theſe Circles into all other Plains, are, in a kind, the ſame with the inſcription of the *Parallels* of Declination: Only, whereas in inſcribing of the *Tropicks*, and other *Parallels* of Declination, you take the Hour-lines out of the Dial-Plain, and put them into a *Trigon*; ſo in the inſcription of theſe you muſt take the *Azimuth* Circles out of your Plain, and put them into a *Trigon*, and from thence transfer them back again to your Plain, as in the other: And as the Hour-lines in the other, muſt be firſt drawn upon the Plain; ſo in this muſt the *Azimuths* be firſt inſcribed: And becauſe theſe Circles of *Altitude* are ſmaller Circles of the *Sphere*, as the *Tropicks* and *Parallels* of Declination were, they will upon all Plains (the *Horizontal* excepted) be *Conick* Sections.

CHAP. VII.

A General and Eaſie way to project Hour-lines upon all kind of Superficies, without any regard had to their ſtanding, either in reſpect of Declination, Reclination, or Inclination.

IF a Point be aſſigned upon any Superficies, Flat, or Curved, one or more, wherein the Hour-lines and *Axis* ſhall concur; how to project the Hours to that Point, and to ſet up an *Axis* after the ordinary manner to

give ſhadow to them, without any knowledge how the Dial ſtandeth in reſpect either of Reclination, Declination, or Inclination.

Firſt, To the Point aſſigned (upon any ſide of it) by help of a *Semi-circle*, or other Level, ſtretch out an *Horizontal* Thred, ſerving for the *Horizontal*-line; which line need not be one ſingle line, but may be turned at one or more Angles, provided that it lie (all the parts of it) totally in the Superficies of the *Horizon*.

Secondly, With a *perpendicular* thred held up, project the Sun into the aſſigned Point, and into the *Horizontal* thred, and ſtick in a Pin, or make a mark upon the ſame *Horizontal*-line, through which the ſhadow cutteth, and at the ſame inſtant alſo, take the Sun's *Altitude*.

Thirdly, By the *Altitude* taken find out the Sun's *Azimuth*; this *Azimuth*, what ever it be, is repreſented by the mark formerly made in the *Horizontal*-line or thred.

Fourthly, Apply a Paiſt-Board to the aſſigned Point, and hold it flat, that it may anſwer to the *Horizontal*-thred alſo; and upon this Paiſt-board protract your *Azimuth* by a thred extended from the Point aſſigned for the Centre to the mark upon the *Horizontal* thred. Which done,

Fifthly, By help of that *Azimuth* upon the Paiſt-board protract the *Meridian* Line, obſerving the true Coaſt, and quantity of the Angle from the *Azimuth*; and to the *Meridian* thus found, deſcribe an *Horizontal* Dial for the Place.

Sixthly, Apply the Paiſt-board to it's place again, all things ſtanding right as before; project all the Hours into the *Horizontal*-thred from off the Paiſt-board, and ſet marks upon the ſame Line; for the

the Points of each ſeveral Hour, which marks may be little Knots to ſlip too and fro upon the ſame thred.

Seventhly, Project the *Meridian* Point by a *perpendicular* Thred upon ſome Object, into that place whereabouts you imagine the *Axis* of the World would paſs, above or below, from the Point aſſigned for the Centre.

Eightly, With your *Semi-circle*, (or a String and Quadrant,) elevated or depreſſed, (as it ſhall be required,) from the Point aſſigned for the Centre, according to your Latitude, project the Pole of the World.

Ninthly, Extend a Thred from the Point aſſigned for the Centre to the Poles of the World, which ſhall repreſent the *Axis*.

Tenthly, By the Point upon the *Horizontal* Thred, and this *Axis*, (either by your Eye, laying the *Axis* to the Hour Points, or laying the Hour Knots to the *Axis*,) you may project all the Hours, and draw them:—— Or elſe you may let the *Axis* alone, and content your ſelf with the Pole point projected into the *Meridian*: For if from the Point aſſigned to be the Centre, or meeting of the Hours, and *Axis*, you extend a Thred to each Hour Point in the *Horizontal* Line, and do repoſe (with your Eye) the ſame Thred upon the Pole Points; then ſhall the ſhadow of the Thred give you that Hour-line; and do ſo in all the reſt.

Eleventhly, Your Thred, or *Axis* lying in it's true ſituation, you may eaſily fit an *Axis* to the ſame poſture. If your Dial be deſcribed upon a plain Superficies, you may then (by one ſide of a Square, applied to the Thred, or *Axis*, and the other ſide lying upon the Plain) find out the *Subſtile*, and meaſure from it the Elevation of the *Axis* above the Plain —— But

if

if the Dial be deſcribed upon a Curved Superficies, you muſt be content to ſet up your *Axis* by the direction of the Thred only.

Twelfthly, This point aſſigned for the Centre, being a Point of the *Axis*, is, as it were, the *Apex* of the *Gnomon*, unto which all the Work is projected: But if it be required to ſet up an *Axis* to ſuch a Superficies upon which the Hours and *Axis* will not meet in any tolerable manner, becauſe perhaps the *Axis* may be but of very ſmall Elevation above the Superficies, and yet an *Axis* is required, in this caſe ſet up any point (of Wire, or ſuch like) of ſuch diſtance from the Superficies, as that the Hours and *Axis* may be diſtinct, and through that point let it be required to make the *Axis* paſs; you have no more to doe but only to project to this point as before, by letting the ſhadow of a *perpendicular* thred paſs through that point, and noting the ſame upon the *Horizontal* thred, and counting that end of the Wire as your Centre, proceed as before; for the thred that lies to project the Hours is a pattern for the *Axis*.

This Way is general, ſerving to project the Hour-lines upon many Superficies, be they Plain or Curved, and however ſituate, whether contiguous or ſeparate, and that without any laborious inquiſition of any of their ſituations in reſpect of Declination, Reclination, or Inclination.

CHAP. VIII.

How from a Glaſs, Horizontally placed, to Reflect-hours upon any Superficies Flat or Curved, one or more.

FIrſt, The Glaſs being placed truly *Horizontal*, obſerve the ſpot of Light that the Sun caſts, and make a Mark at it.

Secondly,

Secondly, And obſerve immediately the Sun's *Altitude*, and find the *Azimuth*.

Thirdly, Then extend an *Horizontal* thred in the ſame Level with the Glaſs, but within the Room.

Fourthly, Project the *Azimuth* into the *Horizontal* thred, by holding up a *perpendicular* thred in ſuch a place, that though it hang at liberty you may at once diſcern both the mark of the ſpot of Light and the Glaſs likewiſe; and then obſerve where the *perpendicular* thred ſeems to cut the *Horizontal* thred, and at that apparent interſection make a mark upon the *Horizontal* thred for the *Azimuth*.

Fifthly, Apply a Paiſt-board to the Glaſs, ſo that it may be ſtayed upon ſome reſt, that after it is taken away it may be reſtored to it's place again with all exactneſs: Let it be alſo placed Horizontally, ſo that it may have full relation to the *Horizontal* thred.

Sixthly, At the Glaſs's Centre make a point for the Centre upon the Paiſt-board, and extending a thred from the Centre of the Paiſt-board to the mark of the *Azimuth* upon the *Horizontal* thred, draw upon the Paiſt-board that line which the extended thred figures out thereupon; afterwards unto the ſame *Azimuth* upon the Paiſt-board draw a *Meridian* line, and to it an *Horizontal*-Dial; and applying the Paiſt-board again to it's firſt ſituation, project the hours thereon unto the *Horizontal* thred, and there make marks, or knots.

Seventhly, Then project the *Meridian* (by a *perpendicular* thred, covering, in appearance, both the Knot at 12, and the Glaſs) unto the contrary Coaſt to that wherein the Pole is elevated above the *Horizon*; that is to ſay, in our Northern Climates, you muſt project the Meridian Southward from the Glaſs, becauſe the North Pole is elevated: And in the Meridian, elevate your *Semi-circle*, or extend a thred and quadrant from the Glaſs Southwards till the Plummet fall upon your Latitude, ſo ſhall it point out, upon ſome Object ſet to receive it, the North Pole reflected.

Of

Or elſe, if this be not convenient (becauſe in Windows which look towards the *South*, the *North* Pole will be without the Room, and ſo the *Axis* above the Glaſs extended towards that Pole will be without alſo) you may in ſuch Caſes find out the oppoſite Pole to it, that is to ſay, that Pole which the former reflected *Axis*, being extended through the Glaſs, and below it, would ſign out, and that may be effected in this manner.

Eighthly, Project the Meridian Line towards the Pole that is elevated, that is with us, towards the *North* Pole; and then (becauſe the *North* Pole is elevated by reflection towards the *South*, ſo, by the ſame reaſon, the *South* Pole muſt be depreſſed towards the *North*) by your *Semi-circle*, or ſtring and quadrant, directed even with the Centre of the Glaſs, expreſs or project your Latitude downwards, (but towards the *North*,) ſo ſhall the *Semi-circle*, or thred, point out the reflected *South* Pole in the Meridian. Now, whether you will, or can, (moſt conveniently,) uſe the reflected *North* Pole above the Glaſs, or the reflected *South* Pole below it, you are to take your Choice, for both the one, and the other of them do repreſent the reflected *Axis* of the World.

Ninthly, By this reflected *Axis*, and the Hour points ſigned out upon the *Horizontal* thred, you may eaſily Project the reflected Hours, upon any kind of Superficies, one or more, whatever they be, that ſtand in the way.



FINIS.